7 Meckel's Cave

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Case Presentation

A 45-year-old woman with a past medical history of hypertension presented to the emergency department with new onset of left-sided jaw and facial numbness, as well as intermittent mild left frontal headache. On physical examination, she was noted to have dysesthesias over the left side of her face and jaw, and slight tongue deviation to the right. Magnetic resonance imaging (MRI) of the brain revealed an extra-axial, dumbbell-shaped, left middle fossa lesion. The mass was considered "benign" but compressed the pons. The patient was told to obtain serial brain MRI scans at 3-month, 6-month, and 1-year intervals. These MRIs revealed interval growth of the lesion, and the patient was referred to our skull base division.

Questions

1. What is the differential diagnosis of the MRI finding?
2. In retrospect, was the period of observation a rational option?
3. How does the unique shape of the tumor influence the selection of surgical approach?

Diagnosis and Assessment

At the time of presentation to our skull base clinic, the MRI showed a well-demarcated, heterogeneously enhancing, dumbbell-shaped mass in the Meckel cave region of the left middle cranial fossa (**Fig. 7.1**). The differential diagnosis was between a meningioma and trigeminal schwannoma, but the latter was favored as it is the most common neoplastic lesion of Meckel's cave. These lesions make up about 33% of Meckel's cave tumors and are classified into three types based on their pattern of growth. Type I lesions are confined to the middle fossa. Type II lesions are dumbbell-shaped due to anterior and posterior extension into the cavernous sinus and posterior fossa, respectively. Type III lesions grow primarily posteriorly through the porus trigeminus into the posterior fossa and exhibit minimal extension into the middle fossa. Other neoplastic lesions are far less common, but still worthy of consideration. These include retrograde extension of head and neck tumors, epidermoid cyst, lipoma, and petrous apex cephalocele.

The dumbbell-shaped Meckel's cave mass in this case measured 3.5 × 3.2 × 2.4 cm in anterior–posterior, transverse, and height. There was extension into the left prepontine cistern with moderate mass effect on the pons. The pontine compression had increased when compared to the patient's initial MRI 1 year previously. The mass extended anteriorly along the middle cranial fossa next to the left cavernous sinus, posteriorly through the porus trigeminus into the prepontine cistern, and inferiorly into the left upper cerebellopontine angle (CPA). In the CPA, the tumor was abutting the left seventh and eight cranial nerve complex. These findings favored the radiographic diagnosis of a type II trigeminal schwannoma.

Trigeminal schwannomas are benign tumors that typically exhibit slow growth. Given the indolent nature of these lesions and the complexity of their surgical management, a period of observation is not unreasonable for most patients at the time of diagnosis. However, the brainstem compression at diagnosis should have raised concern for our patient. When she arrived at our clinic, with radiographic progression over a 1-year period and worsening brainstem compression, few would argue that surgery was the only viable option at this point.

Anatomical and Therapeutic Considerations

Prior to considering the various surgical approaches to this tumor, it is important to take into account the anatomy of the middle fossa, Meckel's cave, cavernous sinus, and the

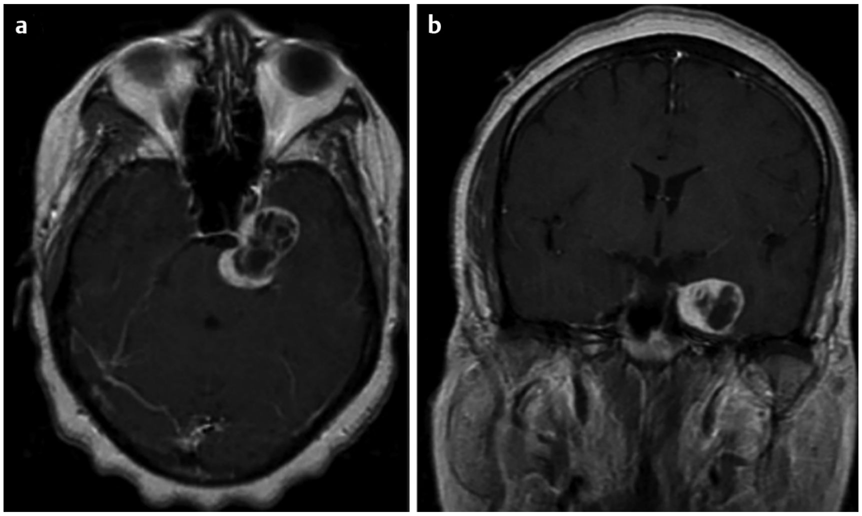


Fig. 7.1 Preoperative MRI. (a) Axial and **(b)** coronal MRI with gadolinium showing a dumbbell-shaped enhancing mass in the region of the left Meckel's cave.

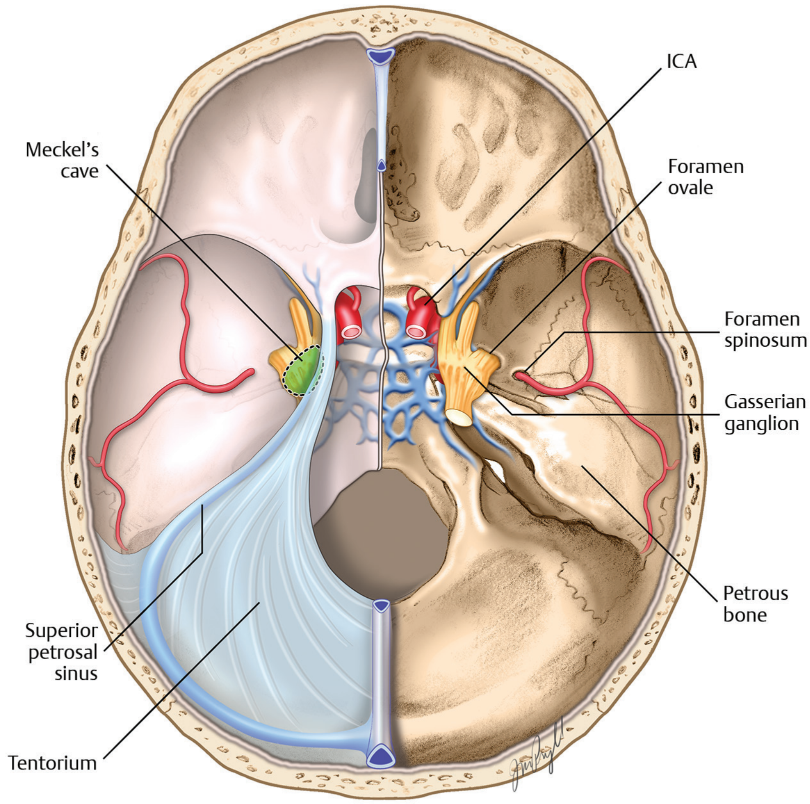


Fig. 7.2 Boundaries of the middle fossa. Schematic illustration showing the boundaries of the middle fossa and relationship of Meckel's cave, petrous bone, superior petrosal sinus, and cavernous carotid artery to each other.

relationships of these structures to one another (**Fig. 7.2**). The middle fossa is bound anteriorly by both wings of the sphenoid bone, posteriorly by the petrous temporal bone, laterally by the squamous part of the temporal bone, and medially by the sella turcica. Just lateral to the sella turcica is the cavernous sinus. The detailed anatomy of the cavernous sinus is beyond the scope of the current discussion but relevant to our patient's tumor; it is important to highlight the two-layer structure of the lateral wall. The superficial, thicker, layer is contiguous with the dura propria of the temporal lobe and forms the dorsal wall of Meckel's cave. The deeper reticular layer is contiguous with the epineurium of cranial nerves III, IV, and VI. The separation of the two layers will be important in surgery.

Meckel's cave sits posterior and lateral to the cavernous sinus (**Fig. 7.3**). It is a three-fingered glove-shaped dural recess containing the gasserian ganglion, V1, V2, and V3 sensory divisions, and the motor rootlets of the trigeminal nerve. Its opening or "mouth" is situated at the petrous apex just below the superior petrosal sinus (SPS). Meckel's cave then extends anteriorly and inferiorly down the anterior face of the petrous bone until the sensory divisions and motor rootlets reach their respective foramina. The petrous and lacerum segments (C2, C3) of the internal carotid artery (ICA) courses within the petrous bone under Meckel's cave.

Our patient's tumor expanded Meckel's cave. In the middle fossa, the anterior "lobe" of the dumbbell tumor involved the lateral wall of the cavernous sinus. The posterior "lobe" of the dumbbell was in the posterior fossa occupying the prepontine cistern. Inferiorly, this "lobe" abutted the VII/VIII nerve complex at the internal auditory canal (IAC).

The most threatening feature of the patient's tumor was its mass effect on the brainstem. Therefore, the primary surgical goal must be to decompress the brainstem. The secondary goal was

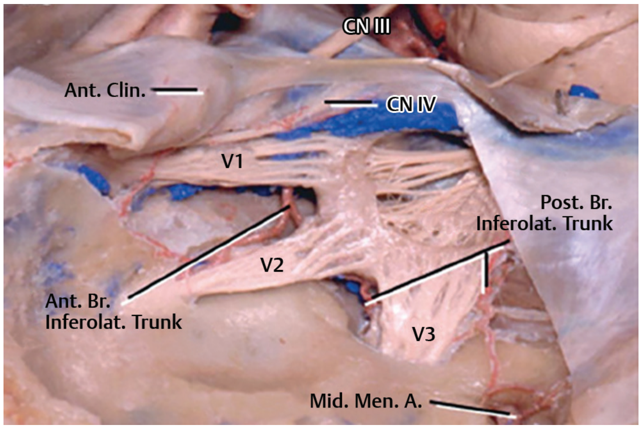


Fig. 7.3 Neurovascular relationship of the middle fossa floor and Meckel's cave (left side). Tentorium and dura of Meckel's cave have been removed. A., artery; Ant., anterior; Br., branch; Clin., clinoid; CN, cranial nerve; Inferolat., inferolateral; Men., meningeal; Mid., middle; Post., posterior. (Reproduced from Stamm A, ed. Transnasal Endoscopic Skull Base and Brain Surgery. 1st ed. Thieme; 2011.)

total resection of the lesion. If the histopathological identity of the tumor was in fact a grade I meningioma or schwannoma, then a total resection would potentially be curative for our patient. Intraoperatively, if portions of the tumor proved to be adherent to critical neurovascular structures, then leaving a small residual would be acceptable as long as the primary goal was met.

Options of Approach

Meckel's cave is unique in skull base surgery, as it can be reasonably accessed with several surgical corridors. In broad terms, the main corridors are anterior, lateral, and posterior, and each has its strengths and weaknesses.

The anterior approach is performed through an endoscopic endonasal transpterygoid approach. The technique requires complete ethmoidectomy, sphenoidotomy, and removal of the posterior wall of the maxillary sinus to gain access into the pterygopalatine fossa (PPF). Then, by following the vidian nerve to identify the pterygoid plate, further bony drilling in this area (with or without sacrificing the vidian nerve and artery) allows enough exposure to follow V2 through foramen rotundum into Meckel's cave (**Fig. 7.4**).

With this technique, there is no need for temporal lobe retraction, which is a frequent cause of neurological injury associated with the lateral approaches. However, the approach requires delicate drilling to expose the paraclival carotid artery and can be technically challenging. Specifically, for our patient, the biggest disadvantage of the endonasal route is the long reach and limited access into the posterior fossa. As the primary goal for her is brainstem decompression, the transpterygoid approach was not her best option.

If the anterior approach has difficulty accessing the brainstem, the posterior approach must logically be considered next as this option puts the surgeon closest to the brainstem. Through the standard retrosigmoid craniotomy, exposure of Meckel's cave is usually blocked by the suprameatal tubercle, a hump of bone at the superior lip of the internal acoustic meatus. However, by removing this tubercle with the drill, access can be gained not only to Meckel's cave, but also to the petrous apex and posterior parts of the middle fossa.

The strength of this retrosigmoid intradural suprameatal approach is the early exposure of the trigeminal nerve at the brainstem, allowing for efficient brainstem decompression. However, for our patient, the attachment of the tumor to the lateral wall of the cavernous sinus would pose significant problems for the posterior approach, even with endoscopic-assisted access into the middle fossa. Just as the anterior approach would have difficulty reaching the posterior lobe of the dumbbell, the posterior approach would have the same problem with the anterior lobe.

Our considerations turn next to the lateral trajectory. This route is centered on a middle fossa craniotomy and subtemporal extradural approach, which would theoretically provide equal access to both lobes of a dumbbell-shaped tumor, balanced at the anterior petrous apex. A middle fossa craniotomy would also gain access to the lateral wall of the cavernous sinus, allowing the mobilization of the two layers of this wall away from each other to detach the tumor from the cavernous sinus. However, what about the posterior fossa? By definition, a middle fossa craniotomy is supratentorial, so what about the exposure into the posterior fossa to accomplish the primary goal of decompressing the brainstem?

The answer to these questions lies with the addition of an anterior petrosectomy. The boundaries of Kawase's quadrilateral are the greater superficial petrosal nerve (GSPN) laterally, mandibular division of cranial nerve V anteriorly, the SPS and petrous ridge medially, and the internal acoustic canal (IAC) posteroinferiorly (**Fig. 7.5**). By supplementing the middle fossa craniotomy with drilling at the Kawase quadrilateral, the posterior and inferior parts of our patient's tumor can be exposed. Furthermore, with the anterior petrosectomy, the surgeon gains control of the SPS and the lateral edge of the tentorium cerebelli. If the latter is cut, further opening into posterior fossa can be gained.

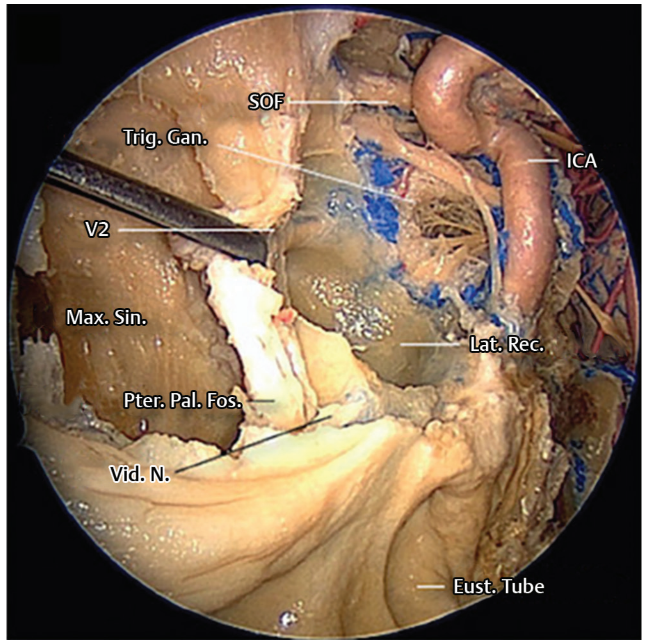


Fig. 7.4 Overview of the endoscopic approach to Meckel's cave. Removal of the posterior wall of the maxillary sinus exposes the pterygopalatine fossa, where the vidian canal and foramen rotundum can be identified. The pterygoid process has to be drilled out to access the lateral recess of the sphenoid sinus. The vidian nerve runs in the floor of the lateral recess, and the maxillary nerve (V2) courses in the lateral wall. Both nerves tend to converge as they travel posteriorly, and are used as surgical landmarks that guide the approach. The vidian nerve, which can be preserved in selected cases, is followed posteriorly until it meets the lateral aspect of the internal carotid artery at the foramen lacerum, and the maxillary nerve is followed posteriorly where it joins the trigeminal ganglion, located posterolateral to the paraclival segment of the internal carotid artery. The superior orbital fissure, which is the anterior continuation of the cavernous sinus, is located anterosuperior to Meckel's cave and anterolateral to the parasellar segment of the internal carotid artery. Eust., Eustachian; Fos., fossa; Gan., ganglion; ICA, internal carotid artery; Lat., lateral; Max., maxillary; N., nerve; Pal., palatine; Pter., pterygoid; Rec., recess; Sin., sinus; SOF, superior orbital fissure; Trig., trigeminal; Vid., vidian. (Reproduced from Stamm A, ed. Transnasal Endoscopic Skull Base and Brain Surgery. 1st ed. Thieme; 2011.)

The main disadvantage of the lateral route is that forceful retraction of the temporal lobe is needed to fully expose the petrous ridge. Furthermore, drilling during the anterior petrosectomy puts the cochlear and petrous carotid at risk, not to mention the cranial nerve VII/VIII complex at the posteroinferior limits of the drilling.

Approach of Choice

Considering all the factors mentioned above, we had a difficult decision to make for our patient. The anterior endonasal approach was deemed too risky for the contents of the posterior fossa, and again, given that the primary goal is decompression of her brainstem, the endoscopic endonasal approach (EEA) was ruled out. The posterior retrosigmoid approach required too long a reach to access the middle fossa, so the final decision was made to use the lateral trajectory. A middle fossa craniotomy will be supplemented with an anterior petrosectomy with the

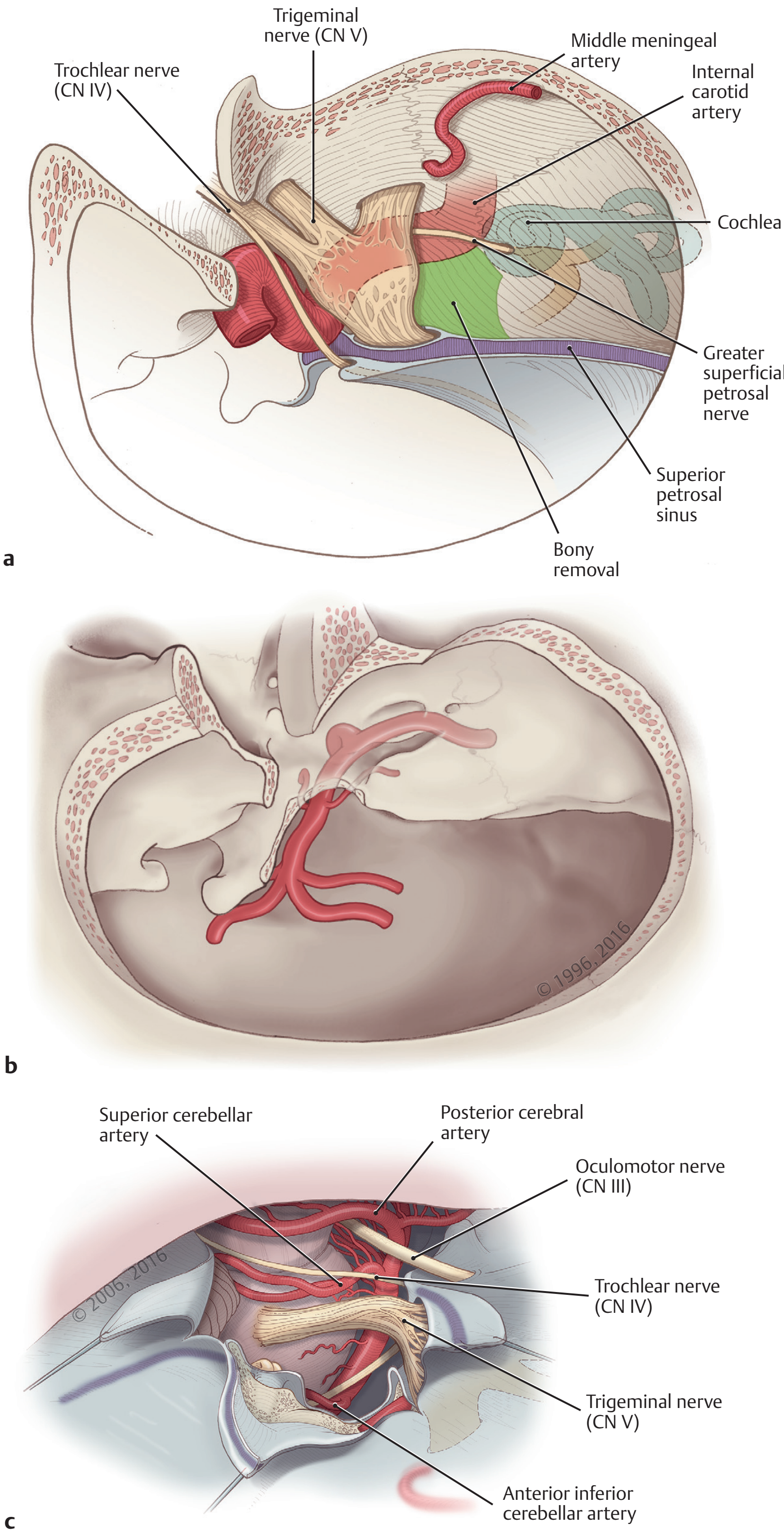


Fig. 7.5 Anterior petrosectomy. (a) Anatomical landmarks for drilling of the Kawase approach. The anterior margin for drilling is the trigeminal nerve, the lateral margin is the greater superficial petrosal nerve, the inferior margin is the internal carotid artery, and the medial margin is the superior petrosal sinus. Posteriorly, the cochlea should be preserved to prevent injury to hearing. The extent of bony removal is depicted (*green area*). **(b)** The anterior petrosectomy provides enhanced exposure to the ventrolateral brainstem. Drilling of the medial apex of the petrous bone increases exposure to the clivus and the upper basilar artery. **(c)** Final anatomical exposure afforded by the anterior petrosectomy. (Reproduced from Spetzler R, et al. Color Atlas of Brainstem Surgery. 1st ed. Thieme; 2017.)

aim of decompressing the brainstem, and mobilization of the lateral wall of the cavernous sinus to potentially fully resect this patient's tumor to prevent recurrence.

Questions

1. How are the boundaries of Kawase's quadrilateral identified during surgery?
2. What are the critical structures that may be "at risk" during an anterior petrosectomy?
3. If incision of the tentorium is necessary, how and where does one start? What structures are "at risk" during this incision?

Description of the Technique

Prior to positioning the patient for the surgical approach, the patient was intubated under general anesthesia and placed in the lateral position for placement of a lumbar drain. This will be used during surgery for brain relaxation. The patient was then positioned supine with a shoulder roll under the left shoulder. The thorax was elevated about 10 degrees to facilitate venous drainage. The head was rotated toward the right shoulder to a position almost parallel to the floor. The neck was slightly extended and the head was inferiorly tilted so that the zygoma was the highest point in the surgical field. This head position allowed gravity to assist the mobilization of the temporal lobe away from the middle fossa floor. Facial nerve monitoring electrodes were placed prior to sterile draping (see **The Three Approach Elements**).

The Three Approach Elements

Corridor: subtemporal

Craniotomy: middle fossa

Modifiers: anterior petrosectomy

A question mark–shaped incision was then made starting from the tragus, curving upward, posteriorly, and anteriorly again.

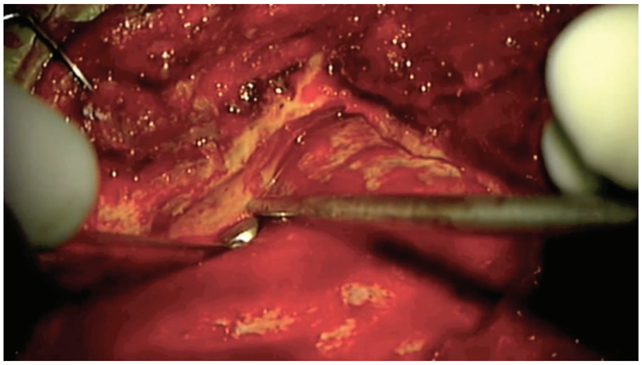


Fig. 7.6 Middle fossa floor. Extradural elevation of the temporal lobe dura off the middle fossa floor was performed with the Penfield number 1 dissector.

The temporalis muscle was incised and reflected with the skin flap anteriorly inferiorly. A posterior myofascial cuff was left to assist with temporalis closure at the end of the surgery. The temporal root of the zygoma was exposed and a burr hole was placed just above it. A 5×5 cm square-shaped middle fossa craniotomy was then made, and the remaining lip of bone at the inferior aspect of the craniotomy was rongeured down flush to the middle cranial fossa floor. At this point, the lumbar drain was opened to drain cerebrospinal fluid (CSF) to facilitate brain relaxation.

The Anterior Petrosectomy

The temporal lobe was elevated in an extradural fashion using a Penfield number 1 dissector (**Fig. 7.6**) until the superior bony petrous ridge was delineated. The middle meningeal artery, found at the foramen spinosum, was coagulated and then divided, allowing further elevation of the temporal lobe dura. The GSPN and V3 were then visualized, and the identity of the former was confirmed using the facial nerve stimulator. The anterior petrosectomy started with drilling posterior to V3 and medial to the GSPN, and it became evident that the tumor had eroded much of Kawase's quadrilateral (**Fig. 7.7**).

The drilling uncovered the ICA in its horizontal petrous portion inferolateral to the GSPN. It was noted that the GSPN and the arcuate eminence (AE) formed the expected 120-degree angle. The direction of the IAC was estimated by bisecting this angle, and the drilling proceeded over the meatal plane to identify the entire course of the IAC. The drilling continued posteriorly and inferiorly toward the inferior petrosal sinus by following the dura of Meckel's cave into the posterior fossa. The facial nerve (cranial nerve VII) was then uncovered as it traveled from the fundal area of the IAC (lateral) to the GSPN and the geniculate ganglion, while avoiding the cochlea situated just anterior to the IAC fundus. The cortical bone at the junction of the ICA and IAC was carefully removed until the lighter color and harder bone of the otic capsule were encountered. The cochlea

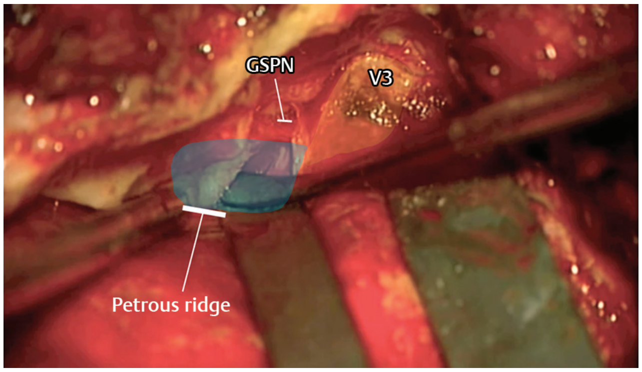


Fig. 7.7 Kawase's quadrilateral. View through the operating microscope of the middle fossa floor prior to anterior petrosectomy. The faintly yellow shaded area is V3 and the blue shaded area denotes Kawase's quadrilateral. Note that the dissector is showing that the petrous ridge that was partially eroded by the patient's tumor. GSPN, greater superficial petrosal nerve.

was “blue-lined” and after this the anterior petrosectomy was complete (see **Operative Setup**).

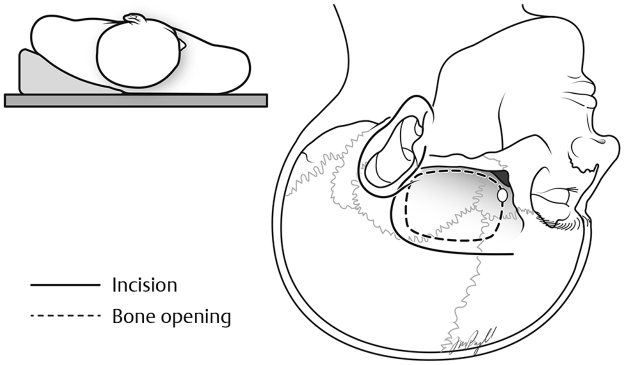
Operative Setup

Position: supine with head turned almost 90 degrees to the right

Incision: question mark, starting just anterior to tragus

Bone Opening: middle fossa, approximately 5 cm^2

Durotomy: parallel to the middle fossa floor, parallel to brainstem



The Posterior Fossa

The dura was opened next to the middle fossa floor and parallel to it. Then, by elevating the temporal lobe, the tentorium was exposed. The posterior fossa dura, exposed via the anterior petrosectomy, was opened parallel to the brainstem. Where the two perpendicular dural incisions met, the SPS was coagulated and divided.

The tumor was then debulked using an ultrasonic aspirator. Cranial nerve V was identified at its brainstem origin and was found to be completely entangled with the tumor. As such, this was detached from the brainstem by incising the involved rootlet. The tentorium, already cut where the SPS was divided, was further incised medially until the incisura, exposing the trochlear nerve (**Fig. 7.8**). The final tentorial cut released the tumor significantly, allowing the tumor to be dissected off the pons (**Fig. 7.9**). The tumor was completely removed from the posterior fossa at this point and brainstem decompression was achieved.

The Middle Fossa

The anterior half of the tumor was debulked using the ultrasonic aspirator to gain further exposure toward the cavernous sinus. The last remnants of the tumor within Meckel’s cave and adjacent to the cavernous sinus were completely removed by mobilizing the lateral wall of the cavernous sinus. To achieve this, V2 and V3 were identified at foramen rotundum and ovale, respectively, and their outer dural covering—the dura propria—was dissected away while maintaining the integrity of the inner reticular layer. In such a way, the tumor adherent to the cavernous sinus wall was removed with minimal harm to the cranial nerves of the cavernous sinus, and safeguarding the intracavernous ICA.

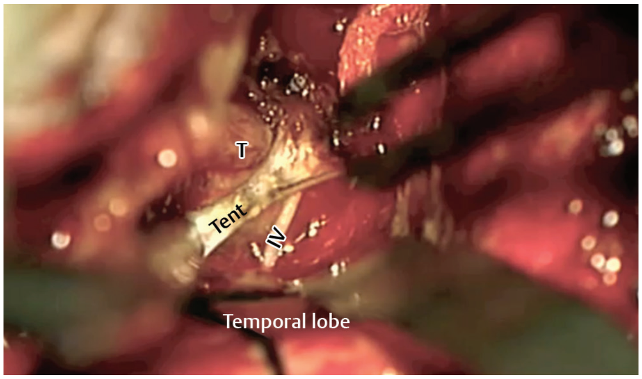


Fig. 7.8 Tentorial incision. With the incision of the tentorium nearing completion, one can see the trochlear nerve (IV) at the incisura. The release of the tentorium reduces the compressive forces of the tumor (T) against the brainstem.

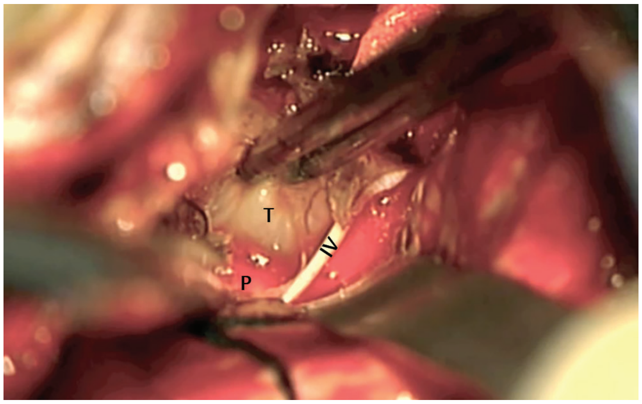


Fig. 7.9 Brainstem decompression. With the incision of the tentorium complete, the tumor (T) can finally be dissected away from the pons (P). IV, trochlear nerve.

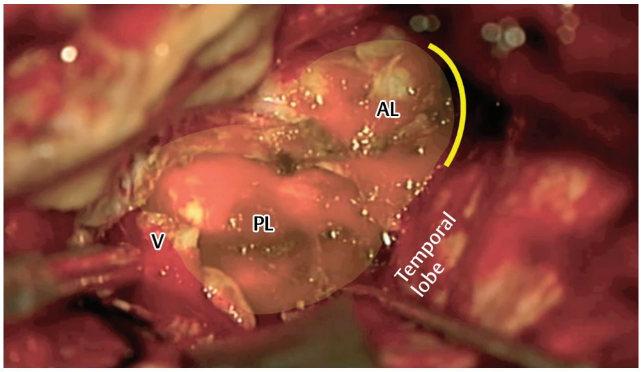


Fig. 7.10 End of resection. The faintly yellow area denotes tumor “bed” after the complete removal of the mass. The *yellow line* indicates the lateral wall of the cavernous sinus from which the tumor was detached. AL, anterior lobe; PL, posterior lobe of the dumbbell tumor; V, stump of trigeminal nerve.

At the end of the resection process, all visible tumor had been removed (**Fig. 7.10**). The temporal lobe was unharmed. The facial nerve responded with 0.5 mA of stimulation from the brainstem underneath the dural covering. The large air cells encountered during the initial approach were packed with collagen-based dural substitute, and a piece of temporalis muscle was harvested and placed over the petrous apex defect. The dural edges were approximated together with sutures and exposed mastoid air cells were plugged with wax. After the bone flap was replaced and skin closed, the lumbar drain was left in place during the immediate postoperative period.

An edited version of the video from this operation accompanies this text (**Video 7.1**).

Surgical Pearls

1. An anterior petrosectomy is a very "deep" undertaking, as there is a significant distance between the craniotomy opening and where the drilling takes place. As such, there is also a lot of temporal dura that must be elevated, and protection of the temporal lobe is paramount. Positioning the head to allow gravity to assist the retraction mitigates the risk of injury. The use of a lumbar drain is controversial, but it is the senior authors' custom to use this to lessen the necessary retraction force.
2. Cochlear injury is unfortunately common during anterior petrosectomy, and it is the basal turn of the cochlea that is most commonly violated during this approach. Important landmarks for identifying the cochlea include GSPN, geniculate ganglion, IAC, and the petrous ICA; however, no definite landmark for the cochlea is established because extensive anatomical variations exist between patients. The basal turn is typically medial to the geniculate ganglion in the angle between the labyrinthine segment of the facial nerve and the GSPN (**Fig. 7.11**). The mean distance between the medial edge of the basal turn and the medial side of the labyrinthine segment of the facial nerve is 4.4 mm (range 3.7–5.1 mm). During anterior petrosectomy, the bone can be removed laterally until the hard otic capsule is identified. The otic capsule appears distinctly firmer and lighter in color than the typical petrous apex bone. After the GSPN and labyrinthine segment of the facial nerve is delineated toward the fundus of the IAC, *extreme caution* should be taken to avoid injury to the basal turn of the cochlea when drilling deep and medially to the labyrinth segment of the facial nerve and posterior to the posterior genu of the petrous ICA.
3. Fully incising the tentorium is critical to this operation, as without it, the tentorium compresses the tumor against the brainstem. The tentorium incision starts at the SPS. By opening the posterior and middle fossa dura perpendicular to each other, one never needs to search for the SPS as it is inevitably where the two cuts meet. Once the SPS is coagulated, the location to cut the tentorium becomes "self-evident."

Aftercare

The patient did well after her surgery. Her head of the bed was elevated to 30 degrees and lumbar drain was opened to drain CSF at a continuous rate of 5 mL/ho to minimize the chance of CSF leakage. Her initial postoperative examination revealed left facial weakness (House–Brackmann II/VI), and, as expected, left facial numbness. Dexamethasone was started to help manage the patient's facial weakness. Deep vein thrombosis prophylaxis was instituted the afternoon following surgery.

The patient's lumbar drain was clamped on day 5 after surgery and was removed on day 6 as she had no evidence of a CSF leak. The patient was discharged home on day 7 after surgery and by then her facial weakness had completely resolved. Steroids were stopped. MRI after her surgery showed a total resection with decompression of the brainstem (**Fig. 7.12**). The histopathological diagnosis from the resection was a schwannoma with an MIB index (Ki-67) of 1 to 3%.

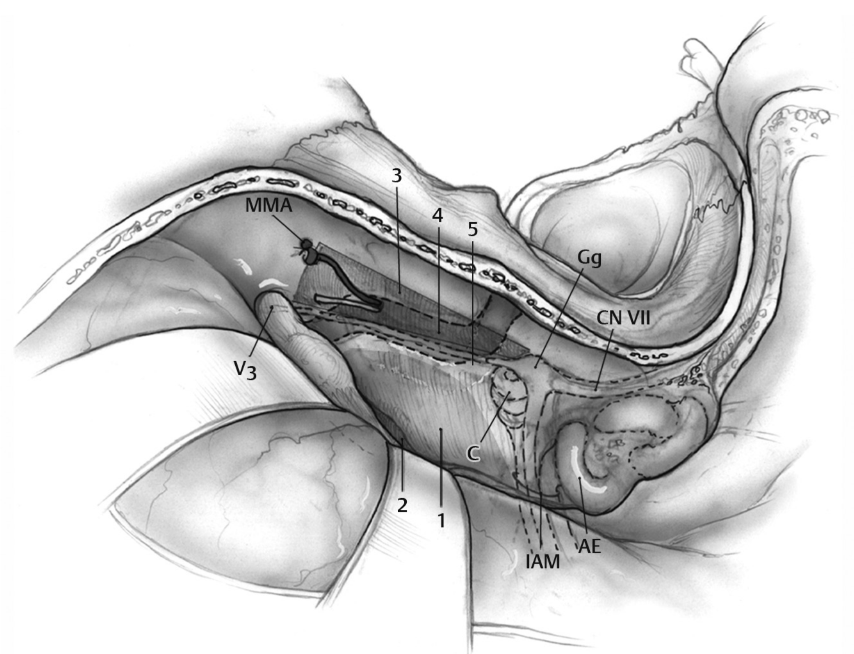


Fig. 7.11 Cochlea at the middle fossa floor. Note the location of the cochlea. The basal turn is medial to the geniculate ganglion, in the angle of the labyrinthine segment of the facial nerve and the GSPN. 1, Kawase's triangle; 2, trigeminal impression; 3, Glasscock's triangle; 4, petrous carotid; 5, GSPN; AE, arcuate eminence overlying the anterior semicircular canal; C, cochlea; Gg, geniculate ganglion; IAM, internal auditory meatus; MMA, middle meningeal artery; V3, mandibular nerve. (Reproduced from Nader R et al, eds. Neurosurgery Tricks of the Trade. Thieme; 2014.)

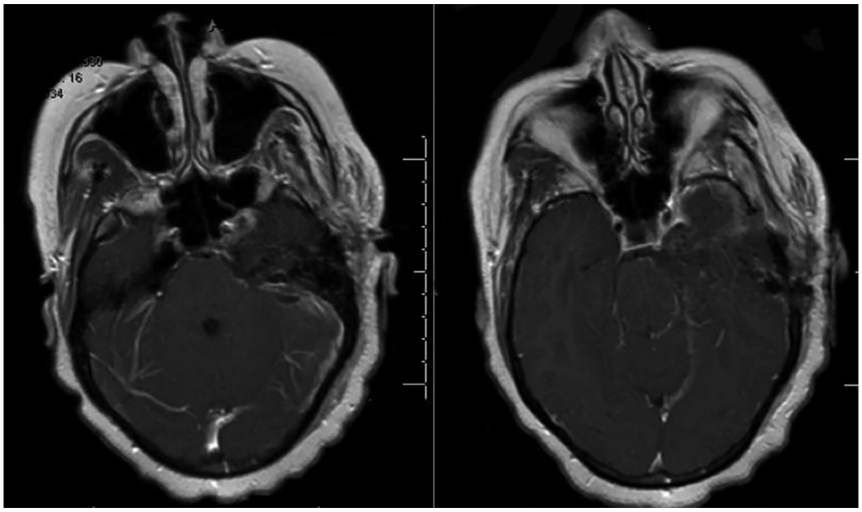


Fig. 7.12 Postoperative MRI. Axial MRI with gadolinium showing a complete resection of the Meckel's cave schwannoma with decompression of the brainstem.

■ Possible Complications and Associated Management

Complications from this operation can be separated into those related to the approach or the resection. An anterior petrosectomy can be complicated by postoperative CSF leak, cranial nerve VII injury, hearing loss, and temporal lobe contusion. CSF leaks and failure in wound healing can be limited by appropriately plugging any exposed air cells with wax, grafted tissue, or dural substitute. Injury to the cranial nerve VII/VIII complex can be minimized by accurately delineating the GSPN, AE, and then the IAC that bisects the angle formed by the former two structures. Drilling away the bone overlying the IAC with a diamond burr under copious irrigation can minimize infiltrating the dural sheath of the IAC and thermal injury to the nerves. If facial nerve palsy happens despite these precautions, it can be managed with a short postoperative course of steroids. To minimize the risk of hearing loss, the cochlea must be avoided during the drilling of the petrous apex. This has been discussed in the "Surgical Pearls" section. The temporal lobe can be contused if overvigorous retraction is used to expose the floor of the middle fossa. CSF diversion and using the least retraction necessary are potential ways to avoid this.

Resection-related complication can be minimized by meticulous microsurgical techniques while maneuvering around the brainstem. Cranial nerves IV through VIII can be adherent to the tumor capsule in varying degrees in the posterior fossa and tentorial incisura, and if so, must be carefully dissected free. Mobilization of the lateral wall of the cavernous sinus can not only maximize the degree of tumor removal, but also moves the cavernous sinus out of harm's way. "Wandering" into the cavernous sinus with the resection tool can have catastrophic consequences especially when the ICA is penetrated.

Perspective

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■ Introduction

Tumors involving Meckel's cave are complex surgical challenges because of the delicate structures surrounding the area. No single approach provides unlimited access to the entire region, and lesions in the Meckel's cave are frequently multicompartmental, adding to the complexity. As always, clearly established surgical goals and a thorough knowledge of anatomy and techniques are needed to select the ideal access through the safest corridor for each lesion, and, often, a combination of two or more approaches is necessary to achieve a satisfactory outcome.

For the case presented in the preceding section, the objectives for the surgical approach were well-defined as was the anatomy of the case. The middle fossa approach was the best choice for that lesion, as it allowed the access to the anterior portion of the tumor directly and extradurally through a middle fossa peeling. The posterior aspect can be followed through the tumor itself or through an anterior petrosectomy (Shiobara–Kawase approach).

We will present an alternative case and focus on the EEA.

■ Case Presentation

A 67-year-old man presented to our clinic with numbness on the right side of his face (V1–V3) and mild headaches. Imaging studies showed a large heterogeneously enhancing mass, centered in the region of Meckel's cave and medial aspect of the right middle cranial fossa, with extensions to adjacent areas including to the posterior fossa. The most likely diagnosis was a trigeminal schwannoma (**Fig. 7.13**).

■ Anatomical and Therapeutic Considerations

Comparing the images of this case with the previous one, we note that the first case had a larger posterior fossa component and that the lesion was behind the ICA without protrusion into the sphenoid sinus. In contrast, our case had only a small component in the posterior fossa, but did project into the lateral recess of the sphenoid sinus anterior to the ICA, making the EEA the ideal choice for it (**Fig. 7.13**).

Options for Approach

When the main component of the trigeminal schwannoma is in the middle fossa, but guarded by the ICA anteriorly, a middle fossa approach with extradural peeling is the approach of choice. This option has been thoroughly discussed. When the main component of the trigeminal schwannoma is in the posterior fossa with only a minor portion in Meckel's cave, then a retrosigmoid approach can be used. In this situation, Meckel's cave itself can be reached by drilling of the suprameatal tubercle, often performed with endoscopic assistance.

Another treatment strategy which is gaining popularity among skull base surgeons, especially for multicompartmental benign lesions, is a staged approach, whereby multiple surgical procedures are planned to remove the accessible portions of tumor. When the target portion is removed, the operation is halted, respecting the safety limits of the approach. A second stage, using a separate approach specifically chosen for the remaining portion of the tumor, is done after an adequate time

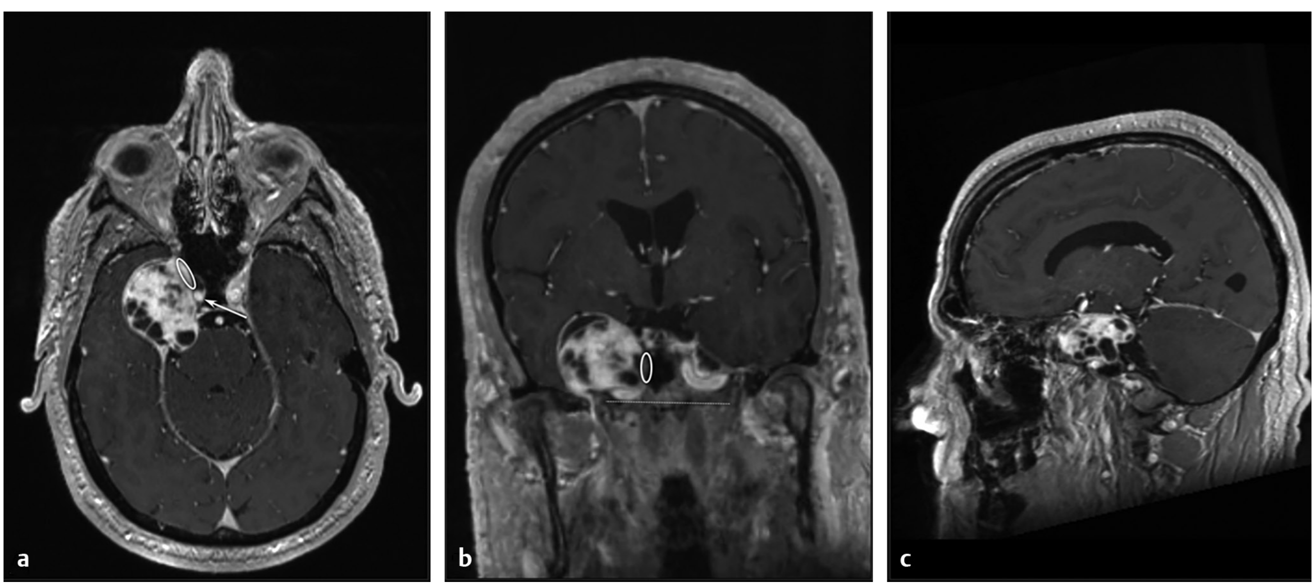

Fig. 7.13 Preoperative images. Contrast-enhanced MRIs. **(a)** Axial view. Note the internal carotid artery (ICA) was pushed posteriorly (*arrow*) creating an unobstructed trajectory to the tumor (*oval*). **(b)** Coronal view. A similar access to the tumor can be identified (*oval*), further aided and increased by the caudal displacement of the ICA when compared to the contralateral (*thin line*). **(c)** Sagittal view. The posterior fossa component was small.

interval from the first stage. The advantage of this strategy is in harnessing the strength of each approach, as only the portion of the tumor most accessible to it is removed. The weakness is subjecting the patient to multiple surgeries, possibly compounding the risks of each stage.

Approach of Choice

Returning to our patient, his tumor projected into the sphenoid sinus anterior to the carotid artery, and this anatomical nuance can be exploited for direct surgical access. Indeed, the EEA, using the anteromedial corridor to access Meckel's cave, is uniquely suitable for this tumor (**Fig. 7.14**).

This technique starts with an endoscopic transpterygoid approach, and the vidian canal is followed until the petrous ICA is located. The bone covering the paraclival and parasellar carotid is removed, followed by extensive removal of bone around foramen rotundum. Access to Meckel's cave is thusly achieved through the quadrangular space which is bounded by ICA inferiorly and medially, V2 laterally, and the abducens nerve superiorly. The resulting corridor provides a direct ventral trajectory to reach the anterior and inferomedial aspects of Meckel's cave. No other corridors can provide this access, because for lesions in this area, the trigeminal nerve itself blocks the approach from all other directions.

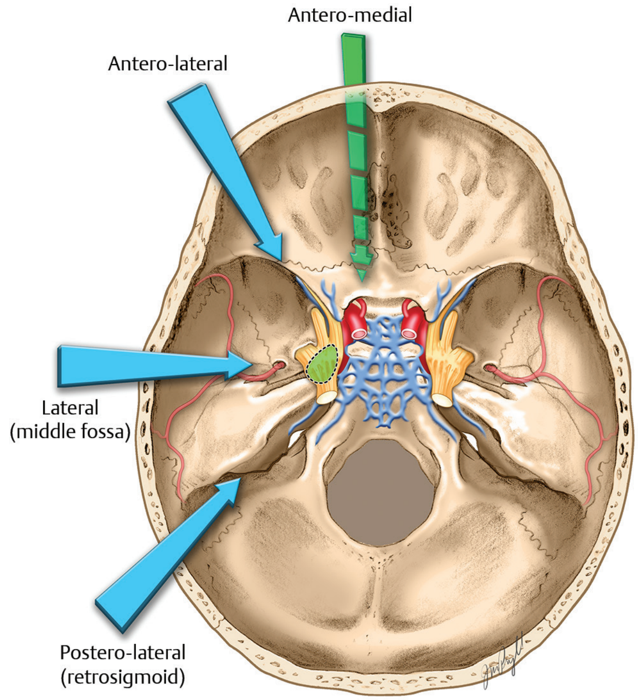

Fig. 7.14 Options for approach. The endoscopic endonasal transpterygoid approach using the anteromedial corridor is uniquely suited for Meckel's cave tumors with small posterior fossa components, projected into the sphenoid sinus, that lie anterior to the internal carotid artery. Tumors that predominantly occupy the inferomedial aspect of Meckel's cave are best approached through the endoscopic endonasal approach, as the trigeminal nerve blocks the approach from all other directions. Green area, Meckel's cave.

■ Description of the Technique

The approach was performed with an otolaryngologist and neurosurgeon working together using two-surgeon four-handed technique. The patient was positioned supine with the head tilted left and slightly turned to the right in a rigid three-pin head holder. Topical oxymetazoline was applied to the nasal cavity for vasoconstriction, and image guidance was utilized.

To begin, the transpterygoid approach started with resection of the right middle turbinate, lateralization of the left middle turbinate, and outfracture of the inferior turbinate bilaterally. A pedicled nasoseptal flap was elevated for later use in reconstruction, and this was done from the contralateral side of the approach to make sure the arterial pedicle would be preserved. A posterior nasal septectomy (1.5 cm), wide bilateral sphenoidotomies, and posterior ethmoidectomies were done. The basopharyngeal fascia was then stripped away from the undersurface of the sphenoid floor, which was drilled down to the level of the clival recess (**Fig. 7.15a**). Next, the vessels emerging from the sphenopalatine foramen (sphenopalatine and posterior nasal arteries) were isolated and coagulated (hence, the contralateral nasoseptal pedicle). A posterior maxillary antrostomy was then performed, and the medial pterygoid plate was identified after lateralization of the contents of the PPF while keeping the periosteum intact.

At this point, the vidian nerve and artery bundle can be clearly seen originating from the vidian canal along the base of the pterygoid plates (**Fig. 7.16**). By following the sphenoid floor from a medial-to-lateral direction, the vidian canal is usually found at the junction of the sphenoid floor as it disappears laterally and transitions to the medial pterygoid wedge (**Fig. 7.15b**). The most critical landmark for transpterygoid approaches is the petrous ICA, and the vidian canal is the guide to identify it. Once the canal was identified, drilling proceeded cautiously along its inferior and medial aspect in an anteroposterior direction toward the foramen lacerum. When the position of the anterior genu (petrous–paraclival transition) was established at the foramen lacerum, bone removal over the ICA proceeded superiorly.

The bone over the anterior genu, horizontal segment, and parasellar carotid protuberance was drilled to eggshell thinness and removed to allow the carotid to be moved laterally without constriction (**Fig. 7.15c**). The medial portion of the clivus at the petroclival junction was drilled down until the lingual process was identified and removed, allowing direct access to periosteum around the ICA. Next, extending the exposure in a rostral direction granted access to the inferior cavernous sinus and quadrangular space and Meckel's cave.

The next landmark is V2. The maxillary antrostomy was widened laterally to expose the posterior wall of the maxilla and isolate this nerve, which was followed superiorly to the foramen rotundum. Bone removal was extended until V2 pierces the dura mater of the middle fossa. The bone between V2 and the vidian canal was also removed toward the junction of the horizontal petrous segment and the anterior genu (**Fig. 7.15d**).

As mentioned previously, the entry into Meckel's cave was through the quadrangular space bounded by the paraclival ICA medially, the horizontal segment of the petrous ICA inferiorly, the dura mater of the middle fossa and V2 laterally, and the abducens nerve superiorly (**Fig. 7.17**). Cranial nerves III, IV, and VI, as well as motor V were monitored during the surgery and a window with no cranial nerve response after stimulation

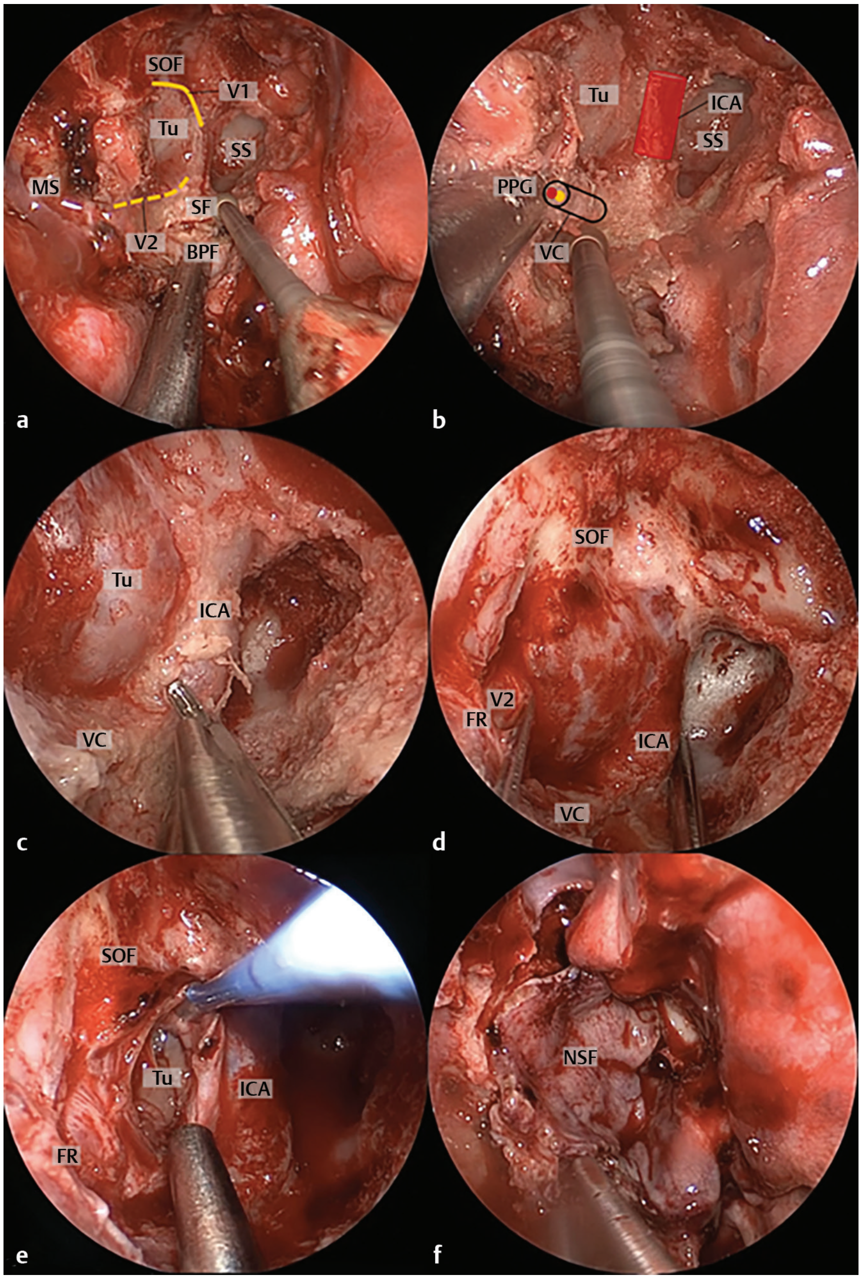

Fig. 7.15 Intraoperative images of the endoscopic endonasal approach for resection of the tumor. **(a)** After the initial steps, the basopharyngeal fascia was stripped away from the sphenoid floor, which was drilled in a medial-to-lateral progression to identify the vidian canal. Note the tumor bulging into the lateral recess of the sphenoid sinus, displacing V1 and V2 from their normal positions. **(b)** The pterygopalatine ganglion was lateralized and the vidian canal (containing the vidian nerve and artery), once identified anteriorly, was followed posteriorly from its inferior aspect to identify and expose the anterior genu of the ICA, which lies superiorly to the vidian canal. **(c)** Using the vidian canal as a landmark, the anterior genu of the ICA was identified and the bone over it was drilled and removed. **(d)** Once the bone over the carotid was removed, the landmarks were confirmed visually and, with the assistance of nerve stimulation and micro-Doppler, a window with no nerve response was defined. Through this window, we proceeded with tumor resection. **(e)** After dural opening, the tumor can be identified, debulked, and resected protecting the cranial nerves and the ICA. **(f)** Reconstruction of the defect was done using an inlay collagen matrix and the nasoseptal flap. BPF, basopharyngeal fascia; FR, foramen rotundum; ICA, internal carotid artery; MS, maxillary sinus; NSF, nasoseptal flap; PPG, pterygopalatine ganglion; SF, sphenoid floor; SOF, superior orbital fissure; SS, sphenoid sinus; Tu, tumor; V1, orbital division of the trigeminal nerve; V2, maxillary division of the trigeminal nerve; VC, vidian canal.

was defined. The tumor was entered at the level of V2, and the trigeminal nerve was only completely visualized at the end of the resection, since it was laterally positioned. Following the tumor posteriorly, the whole tumor, including the posterior fossa component, was removed with no intraoperative complications (**Fig. 7.15e**).

Reconstruction was performed not only using the nasoseptal flap, but also autologous fat graft was placed protecting the ICA from desiccation and/or trauma (**Fig. 7.15f**).

Aftercare

Postoperative examinations confirmed a total resection (**Fig. 7.18**). A few days later, the patient presented with fever and elevated white blood cell count. A CSF sample confirmed high white cells with negative cultures, and the patient received 14 days of intravenous antibiotics. He was discharged with no new neurological deficit on postoperative day 14.

After approximately 8 to 12 months, the facial sensation of the patient normalized and he currently has no complains of facial pain or numbness. Four years having passed since his surgery, the patient has been followed with regular imaging examinations with no signs of recurrence (**Fig. 7.19**).

Commentary

After the pioneering work of Jho and Carrau in the mid-90s outlining the tenets of the technique, the use of endoscopy for skull base surgeries, particularly for transsphenoidal pituitary surgery, has steadily grown in the past three decades spurred by a substantial number of anatomical studies, innovations in monitoring techniques, and refinement of fiber-optic

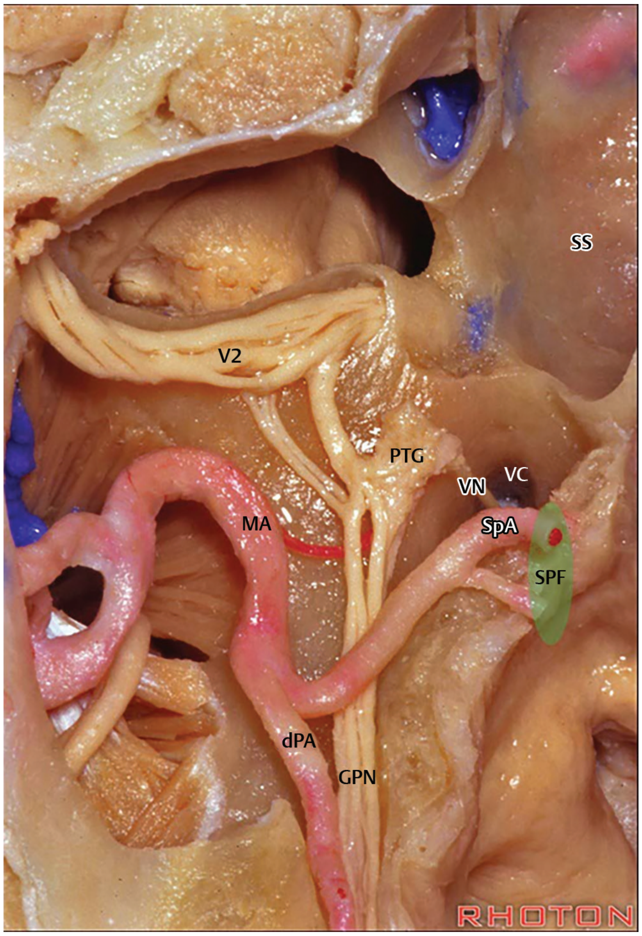

Fig. 7.16 Contents of the right pterygopalatine fossa. The maxillary sinus lies anterior to the pterygopalatine fossa. Removal of the posterior wall of the maxillary sinus in this cadaveric dissection exposes the pterygopalatine fossa. During surgery, the pterygopalatine fossa is exposed after the posterior maxillary antrostomy. The vidian nerve runs in the floor of the lateral recess of the sphenoid sinus. The nerve is followed posteriorly until it meets the lateral aspect of the internal carotid artery at the foramen lacerum. dPA, descending palatine artery; GPN, greater palatine nerve; MA, maxillary artery; PTG, pterygopalatine ganglion; SpA, sphenopalatine artery; SPF, sphenopalatine foramen; SS, sphenoid sinus; V2, maxillary nerve; VC, vidian canal; VN, vidian nerve. (The Rhoton Collection.)

and image-guidance technology. Nowadays, the expanded EEA derived from the continuing collaboration between neurosurgery and otorhinolaryngology has allowed the endoscopic technique to reach an ever-expanding number of lesions and areas of the skull base. These expanded techniques present numerous advantages for different skull base lesions, such as minimal manipulation of the brain, cranial nerves, and blood vessels while offering panoramic exposure of the lesion. It is, on the other hand, a challenging technique with a steep learning curve, requiring dedicated training.

However, it is important to realize that a skull base surgeon must not be a zealot, trying to use the same technique for all patients. A careful analysis of the surrounding anatomy,

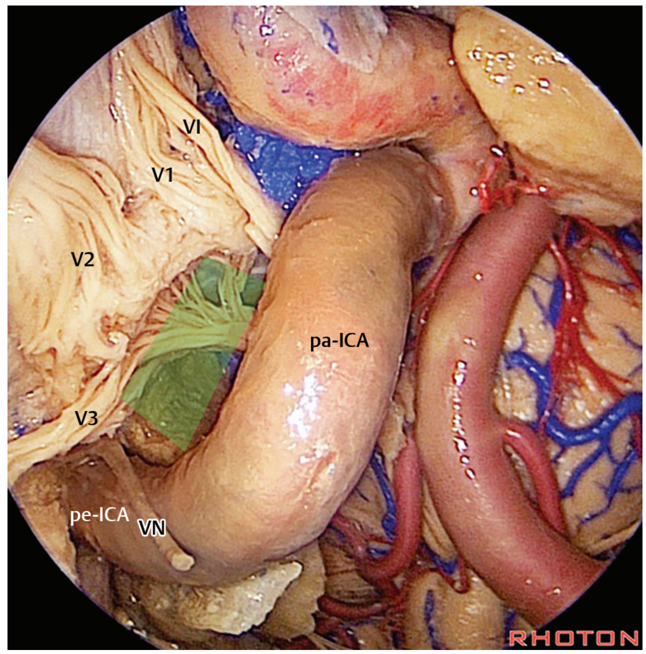

Fig. 7.17 Entry into Meckel's cave. The dura of the middle fossa in this cadaveric dissection has been opened to expose Meckel's cave. The *green shaded area* represents the quadrangular space used for entry into the Meckel's cave. It is bounded the paraclival internal carotid artery medially, the petrous carotid inferiorly, V2 laterally, and the abducens nerve superiorly in the cavernous sinus. Pa-ICA, paraclival carotid artery; pe-ICA, petrous carotid artery; VI, abducens nerve; VN, vidian nerve (The Rhoton Collection.).

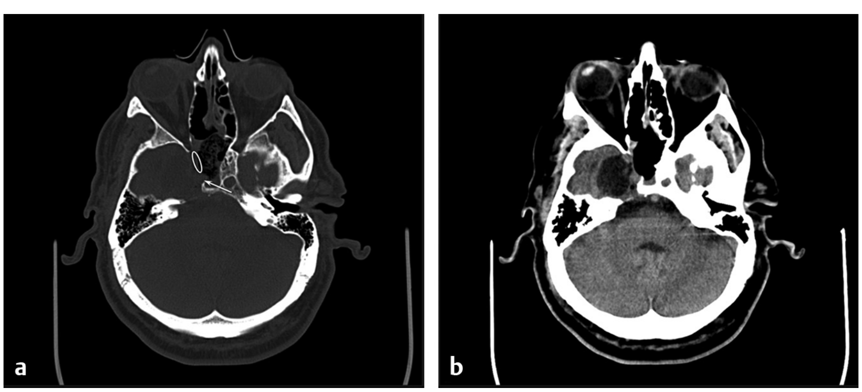

Fig. 7.18 Postoperative CT. (a) Bone window. As planned preoperatively, Mullan's triangle has been opened to communicate the lateral recess of the sphenoid sinus and the middle fossa (*oval*), through which tumor resection was done. Note that the osseous encasement of the internal carotid artery has been removed, preserving the vessel (*arrow*). **(b)** Soft tissue window. A complete resection, including the posterior fossa component has been achieved.

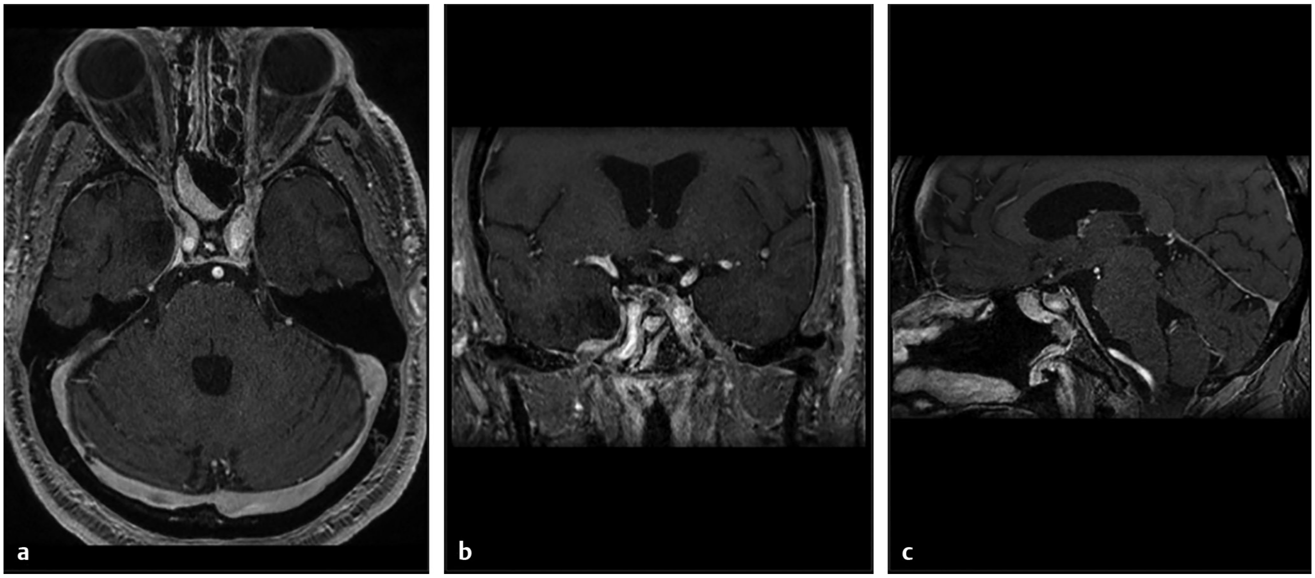

Fig. 7.19 Postoperative MRI at 4-year follow-up. **(a)** Axial, **(b)** coronal, **(c)** sagittal view. The nasoseptal flap used for reconstruction of the defect and protection of the internal carotid artery can be seen enhancing and no signs of tumor recurrence or residual were identified.

particularly relating to the position of cranial nerves and vascular structures is paramount in choosing the safest route to a lesion. Related to trigeminal schwannomas, the EEA is not suitable for tumors blocked anteriorly by the carotid artery, without projection into the sphenoid sinus, with large posterior fossa components. It is, however, uniquely suited for tumors anteromedial to the ICA, occupying the anterior and inferomedial aspect of Meckel's cave. As always, the objectives of the surgery must be clearly defined and the experience of the surgical team carefully assessed, before determining if the EEA is ultimately best for the patient.

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