The Middle Fossa Approach and Extended Middle Fossa Approach: Technique and Operative Nuances

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BACKGROUND: The middle fossa approach and extended middle fossa approach, also known as the anterior transpetrosal approach, are cranial base techniques for addressing small vestibular schwannomas, medial temporal bone lesions, midbasilar trunk aneurysms, and selected petroclival lesions.

OBJECTIVE: To provide an outline of a number of technical nuances that are important to correct application of these approaches, maximizing exposure, and limiting potential morbidity.

METHODS: Via a temporal craniotomy, the petrous apex is removed in variable degrees, depending on the exposure requirements of the lesion. The technique is described in detail with appropriate nuances of the technique provided.

RESULTS: The described nuances of technique in the performance of the approaches have resulted in successful application of these techniques in a significant number of cases.

CONCLUSION: Significant familiarity and practice with these surgical approach techniques are critical to applying them safely to clinical problems. A number of technical details can assist the surgeon in achieving optimal exposure and limited morbidity.

KEY WORDS: Acoustic neuroma, Anterior transpetrosal approach, Brain tumor, Skull base surgery

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The middle fossa approach has been used for a number of years to expose the internal auditory canal (IAC), mainly for removal of small vestibular schwannomas and small meningiomas located at the lip of the internal auditory meatus. Its natural extension has been variously called the extended middle fossa and the anterior transpetrosal approach. This extended technique is used alone or in combination with other techniques to remove the petrous apex via the middle fossa trajectory. The technique has been demonstrated to be useful, particularly in the removal of neoplastic lesions of the petroclival region and cerebellopontine angle.[1-4] Vascular lesions such as midbasilar aneurysms and basilar tip aneurysms have also been approached with this technique or in some combination.[5-7] Such safe exposure of the IAC and removal of the petrous apex remains a relatively unfamiliar technique to neurosurgeons, mostly being performed by neurotologists. This set of surgical maneuvers must be sufficiently rehearsed in the cadaver laboratory before its application clinically. Principally, the significant topographic variability of the middle fossa floor and the relationships to the internal anatomical structures make intimate knowledge mandatory. Thorough familiarity of the neurosurgeon with this anatomy, working in tandem with neurotologists, yields dividends in obtaining optimal exposure. It is possible to know the limits of an approach only with intimate familiarity. Therefore, adequate laboratory preparation and consequent clinical experience are of great importance in these procedures.

A discussion of the technique and its operative nuances is presented based on my experience with these approaches.

ABBREVIATIONS: gspn, greater superficial petrosal nerve; **IAC,** internal auditory canal

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SURGICAL TECHNIQUE

Preoperative Preparation and Positioning

A principal determination in preoperative preparations is the necessity of a standard middle fossa approach vs the extended approach. Generally, small intracanalicular lesions with limited extension into the cerebellopontine angle require only the standard middle fossa approach. Larger lesions involving the IAC and the cerebellopontine angle are better approached via the extended technique. Lesions that extend medial to the porus acusticus and those involving the posterior cavernous sinus generally require the added exposure of the extended approach. The size and extent of the lesion must be carefully assessed on preoperative imaging. Computed tomography scanning without contrast that includes bone windows is helpful to view the morphology of the temporal bone structures in preparation for their dissection. Lesions that are very large and extend below the level of the IAC, lateral to the sagittal extent of the superior semicircular canal, and medial to the petroclival sulcus are typically not suitably exposed with the extended middle fossa approach. Such extensive lesions are better exposed via a combined approach to expand the exposure provided by removal of the petrous apex.

These approaches require a moderate degree of temporal lobe retraction. Thus, the potential exists for temporal lobe injury via direct pressure or venous congestion. Therefore, lumbar drainage is considered as an adjunct in relieving pressure on the temporal lobe while under retraction. A lumbar drain should be specifically considered in cases of an approach on the dominant side. In addition, if the patient is obese or has comorbidities that would elevate the risk of venous congestion and hypertension, lumbar drainage should be considered to assist in relieving temporal lobe pressure under the retractors.

In general, patients are placed supine on the operating table with the head secured in a Mayfield head holder. It is helpful to arrange the operating table so that the surgeon may sit comfortably with the patient's head close to the surgeon. The operating table should be somewhat couched, with the head above chest level to promote venous drainage. The plane of the temporal squama should be parallel to the floor.

In an obese patient or a patient with comorbidities that would indicate a risk for venous hypertension and congestion, the patient is better placed in the lateral position to decrease intrathoracic pressure and to promote venous drainage. In this procedure, the temporal lobe is necessarily retracted, putting it at risk for retraction-induced injury. Any situation that elevates intracranial pressure during the procedure will exacerbate this risk and needs to be mitigated. A further adjunct to be considered, especially when approaching from the dominant side, is placement of a lumbar drain before craniotomy to help relieve pressure on the temporal lobe via drainage of cerebrospinal fluid.

Neurophysiologic monitoring of the facial nerve is standard when these approaches are used. Monitoring of the brainstem auditory evoked potentials may also be helpful in indicating hearing at risk from increase latency of wave V during dissection from a potentially reversible cause. In cases of small vestibular schwannomas in which hearing preservation is attempted, direct monitoring of the cochlear nerve has been found to be quite useful in alerting the surgeon to signal changes that indicate the necessity for a change in technique.

Incision and Craniotomy

Different scalp incisions have been described for these approaches: straight line, curved, and question mark shaped. In my practice, the question mark–shaped incision has been found to be most satisfactory, mainly from the standpoint of optimizing exposure across the middle fossa floor. The incision is made beginning just anterior to the tragus, avoiding the frontalis branches of the facial nerve (Figure 1). The scalp is elevated subgaleal, separating the loose areolar connective tissue layer from the temporalis fascia. This is done in the manner of Yasargil to elevate the scalp while preserving the frontalis branches of the facial nerve.

The temporalis fascia and muscle are incised with monopolar cautery along the line of the incision. The muscle is elevated subperiosteally out of the angle between the zygomatic process and the temporal squama. This will allow mobilization of the muscle in the anterior direction, clearing the soft tissue from obstructing the

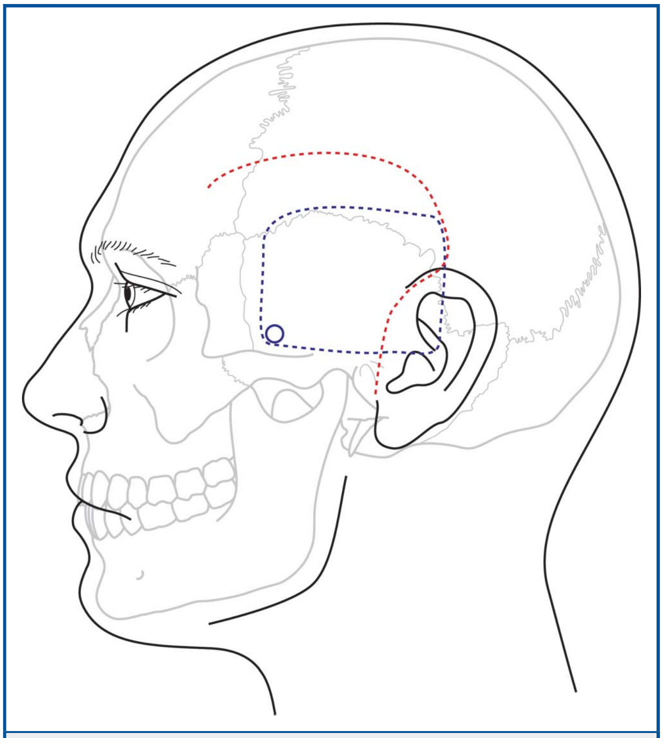

FIGURE 1. *Typical incision (red dashed line) for both the middle fossa and extended middle fossa approaches. The bone flap (blue dashed line) extends from the floor of the middle fossa to just above the squamosal suture in the cephalocaudal dimension.*

view flat across the middle fossa floor (Figure 2; see also Video 1, Supplemental Digital Content 1, http://links.lww.com/NEU/A435, showing a craniotomy and dural elevation). The muscle is elevated subperiosteally in the inferior-to-superior direction to preserve a smooth periosteal layer against the inner aspect of the muscle. Done this way, the vascular supply and innervation of the muscle should be left intact, minimizing the chances of significant postoperative atrophy of the temporalis. This technique of mobilizing the muscle in the anterior direction is designed to obviate the need for zygomatic osteotomy to obtain a favorably flat viewing angle across the middle fossa floor.

The craniotomy is generally made one-third behind and two-thirds anterior to the external auditory meatus. The superior extent of the craniotomy should be at or slightly above the level of the squamosal suture. A cranial window that does not extend high enough in the craniocaudal dimension will be inadequate for bone removal at the middle fossa floor because of limitations in the superior-to-inferomedial viewing angle. Similarly, a narrow craniotomy can result in limitations in exposure. Making the craniotomy in the dimensions of height and width illustrated in Figure 1 helps to distribute retraction forces more evenly across the temporal lobe, lessening the severity of retraction. Particular care needs to be taken in this craniotomy to preserve the integrity of the dura. Multiple or significant breaches in the dura put the temporal lobe at increased risk of injury as a result of the retraction required to perform the petrous bone drilling. If it is anticipated that the dura will be adherent, it is best not to use a craniotome. A more secure technique is to drill a trough in the line of the osteotomies and thin the bone until it is easily fractured to remove the bone flap (see Video 1, showing craniotomy and dural elevation). The dura must be carefully separated from the flap with a sharp curved elevator to lessen the chance of disruption of the membrane. If the dura is significantly damaged, the temporal lobe is covered with a collagen-type barrier. I prefer to use an inlay technique in this situation. A dural incision is made lateral, and the membrane is placed intradural to cover the temporal dura widely, preventing any herniation of the brain through the dural defects. This linear incision is then closed before further dural elevation. This must be done before retraction to prevent temporal lobe herniation through dural defects while under retraction, which can result in damage to the cortex and superficial draining veins.

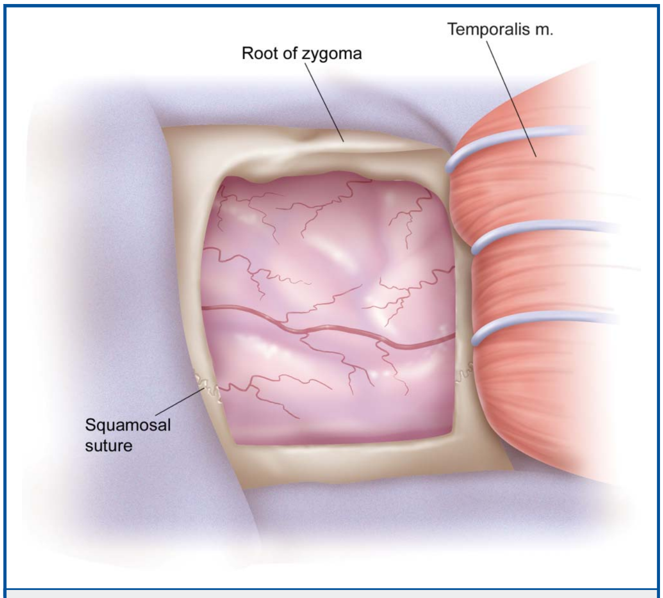

FIGURE 2. *Illustration of a left temporal craniotomy. The temporalis muscle (m.) is reflected anteriorly. The inferior bone margin is flush with the floor of the middle cranial fossa.*

With the flap removed, any remaining lip of bone inferior should be removed to obtain a flat, unobstructed plane of view across the middle fossa floor. This flat view across the floor helps limit temporal lobe retraction. The dura is elevated, and the bone is removed with the drill or rongeurs. Air cells may be opened with this bone removal and should be occluded with bone wax to avoid leakage of cerebrospinal fluid postoperatively.

Dural Elevation and Extradural Dissection

Proper dural elevation is key to avoiding complications and maximizing exposure. The dura is elevated beginning posterior at the petrous ridge working in the medial direction along the ridge (see Video 1, showing craniotomy and dural elevation). It is important to avoid working from lateral to medial in the anterior aspect (ie, medial to the root of the zygoma) to avoid inadvertently damaging or putting traction on the greater superficial petrosal nerve (gspn). The nerve lies in the major petrosal groove and is covered by a thin layer of periosteum. Working from lateral to medial across the floor in this area risks lifting the nerve out of the groove, potentially resulting in traction on the nerve and therefore the geniculate ganglion. This is a potential mechanism for facial nerve injuries in these approaches. Regardless of the dural elevation technique, it is critical to understand the gspn location in the middle fossa floor and to leave the nerve in its groove, protecting it from inadvertent traction.

A second important point regarding dural elevation concerns locating the true petrous ridge. The superior petrosal sinus forms the petrosal groove along the superior aspect of the petrous ridge. It is possible to mistake the upper edge of this groove for the petrous ridge and thereby inadequately elevate the dura. Elevating the dura covering the superior petrosal sinus to locate the lower edge of the groove yields dividends when retracting the dura from the petrous ridge. Properly elevating the dura along the ridge allows the retractor blade tips to properly rest against the petrous ridge and to optimally retract the dura without slipping.

Dura is elevated to expose the meatal plane, which represents the bony roof of the IAC. The meatal plane is the bone bounded by the arcuate eminence, gspn, trigeminal impression, and petrous ridge. The medial limit of dural elevation is the trigeminal impression. At the anterior aspect of elevation, the middle meningeal artery is exposed at its exit from the foramen spinosum. It is helpful to coagulate and divide the artery at this point of emergence to allow better relaxation of the dura. Especially in the anterior transpetrosal approach, it is also helpful to then separate the dura propria from the connective tissue sheath of V3 and the lateral aspect of the gasserian ganglion. This maneuver further allows relaxation of the dura and enhances the mobilization of the dura covering the temporal lobe (Figure 3 and Video 1, showing craniotomy and dural elevation).

During these maneuvers around the lateral aspect of the cavernous sinus, significant venous bleeding may be encountered. Management in a calm, organized fashion is critical to limiting morbidity while controlling hemorrhage and optimizing exposure. Small pieces of Surgicel are useful in judiciously packing bleeding points from the cavernous sinus. It is important to avoid overpacking to limit compression injury to the fifth and sixth nerves and compression of the petrous carotid artery. The preferred method of hemostasis is to pack small amounts of oxidized cellulose into the bleeding points along the lateral margin of V3 and the gasserian ganglion, to cover the area with soft cottonoids, and to apply light pressure and suction. The surgeon can remove these cottonoids later when ready to begin bone removal with the drill. Also of utility is powdered Gelfoam or one of its preparations (eg, Surgiflo, Flo-Seal). These preparations are used by applying them across the bleeding points, covering with soft cottonoids, and applying suction. Given a short period of time, hemostasis will generally be obtained and the cottonoids may be removed.

The dura is optimally retracted with 2 tapered blades placed lateral and medial resting against the true petrous ridge. The lateral blade is best placed along the ridge at or just lateral to the arcuate eminence. The medial retractor blade will hold nicely on the petrous ridge at the lateral edge of the trigeminal impression, especially when the dura propria has been elevated off the lateral aspect of the trigeminal ganglion and V3 as described above.

Bone Removal (Middle Fossa Approach)

Safe bone removal centers on properly identifying the orientation of the IAC, deep to the meatal plane and petrous ridge. A number of methods have been described for this elemental task.[8-12] This author prefers to visualize axis lines along the gspn and the arcuate eminence. These axes form an angle, which is then bisected. The bisection line of this angle is an approximation of the IAC position in the bone (Figure 3). Bone removal is initiated along the petrous ridge where this bisection axis intersects the ridge, just lateral to the trigeminal impression (see Video 2, Supplemental Digital Content 2, http://links.lww.com/NEU/A436, showing bone removal). Significant morphological variability exists in the floor of the middle fossa, contributing to the challenges of this bone removal. Importantly, the arcuate eminence is not a reliable landmark locating the underlying superior semicircular canal. Because of these variabilities, I have found that beginning bone removal at the petrous ridge lateral to the trigeminal impression is most reliable. I have used several of the methods offered for this task but found it more complicated to expose or "blue-line" the superior semicircular canal or to judge a 60° angle from the gspn. Selecting this starting point just lateral to the trigeminal impression at the petrous ridge is a simple method that has worked well in my experience.

With continuous irrigation, bone removal begins with a 3-mm course diamond burr. Irrigation is best provided with a continuous system via a malleable tip mounted at the edge of the wound, which can be oriented so that irrigant continuously washes away bone dust. Alternatively, an irrigating suction-style tip is used. Two important effects of this constant flow of irrigation are that the fluid helps dissipate heat from the burr and keeps the diamond burr clean from bone dust buildup.

Bone is removed to expose the dura at the internal auditory meatus. This dura is identified by the curved shape of the membrane as it enters the IAC. The dura of the IAC is then followed a short distance of several millimeters before working medial to the canal to remove the petrous apical bone on its medial aspect that covers posterior fossa dura. Bone removal continues from medial to lateral, following the dura lining the internal auditory canal. The cochlea is located anterior to the fundus of the IAC, inferior to the geniculate ganglion. The key to avoiding fenestration of the cochlea is to recognize its position in relation to the surrounding anatomy (Figure 4). The bone surrounding this structure is also very compact and is distinguishable from the surrounding cancellous bone of the petrous apex.

The particularly important points to stress in this bone removal concern the completeness of exposure, especially at the lateral end of the canal. It is critical to skeletonize the IAC as close to 270° as possible along its medial aspect. Laterally, the fundus of the canal must be exposed, including the vertical crest and proximal 1 or 2 mm of the facial nerve in its canal. Bone removal must be as complete as possible off the backside of the canal, between the superior semicircular canal and the IAC. Obtaining as complete an exposure as possible cannot be underemphasized in terms of allowing an adequate view to the fundus and optimizing the chances of complete resection of tumor and preservation of the facial and cochlear nerves. In contrast to the extended middle fossa approach, the anterior margin of bone removal approaches the gspn, but the petrous carotid artery is not exposed. Similarly, the inferior limit of exposure of the posterior fossa dura is not to the inferior petrosal sinus. Several millimeters of posterior fossa dura inferior to the margin of the IAC is sufficient (Figure 4A).

Bone Removal (Extended Middle Fossa Approach)

The middle fossa approach bone removal described above is the basic platform for expanding the approach to allow access to a greater area of the cerebellopontine angle and petroclival area by removal of the petrous apex. The extended middle fossa bone removal results in a fenestration through the petrous apex, allowing this expanded view over the basic middle fossa technique (see Video 2, showing bone removal).

On the medial aspect of the exposed IAC, bone is removed in the medial direction toward the clivus. The petrous apical bone is cancellous in nature and can be quickly removed with a diamond

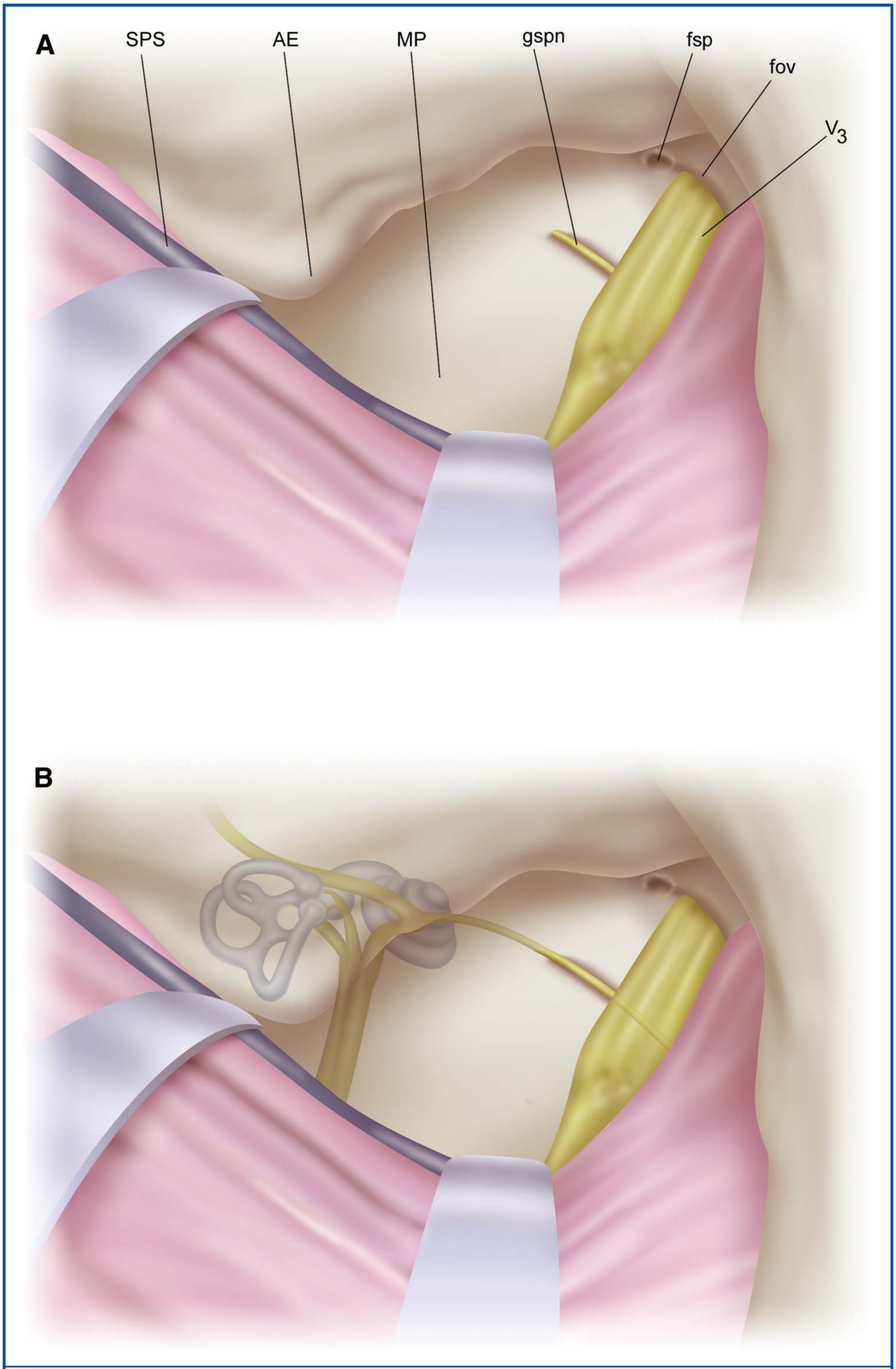

FIGURE 3. **A**, *after dural elevation, the important landmarks of the middle fossa floor are identified. AE, arcuate eminence; fov, foramen ovale; fsp, foramen spinosum; gspn, greater superficial petrosal nerve; MP, meatal plane; SPS, superior petrosal sinus; V3, mandibular division trigeminal nerve.* **B**, *location of the internal auditory canal, cochlea, and labyrinth in the temporal bone relative to the middle fossa floor landmarks.*

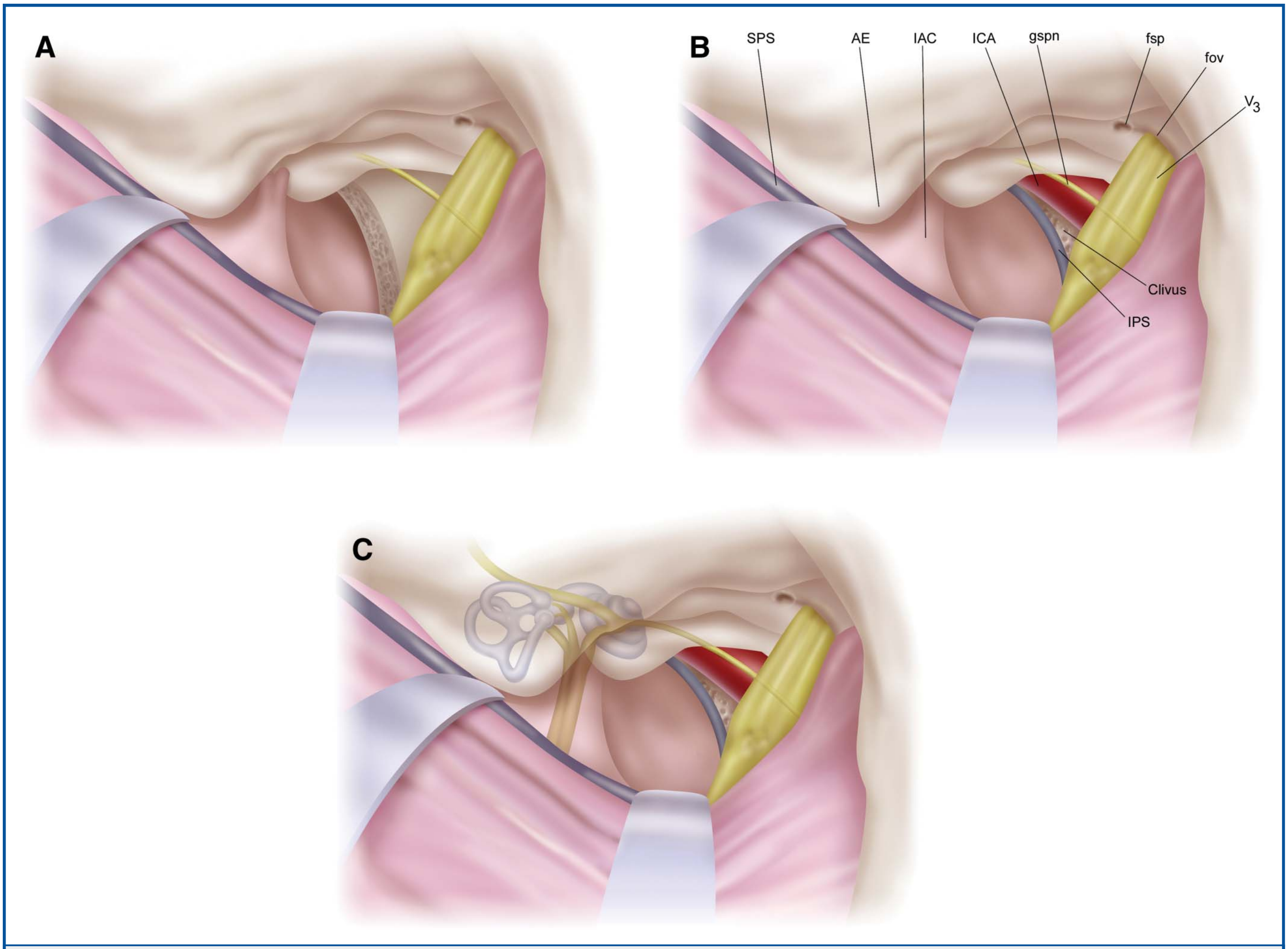

FIGURE 4. **A**, *extradural view after bone removal for the middle fossa approach.* **B**, *general extradural view after bone removal for the extended middle fossa approach. AE, arcuate eminence; IAC, internal auditory canal; ICA, internal carotid artery; IPS, inferior petrosal sinus; fov, foramen ovale; fsp, foramen spinosum; gspn, greater superficial petrosal nerve; SPS, superior petrosal sinus; V3, mandibular division trigeminal nerve.* **C**, *location of internal structures is projected in relation to the surface anatomy.*

burr. On the anterior aspect of bone removal, the horizontal segment of the petrous carotid artery is located inferior to the gspn as it crosses the middle fossa floor. The petrous carotid is generally exposed in this procedure, at least on its posterior aspect. It is best to preserve the gspn in the dissection to prevent the postoperative complication of a dry eye. Bone is removed deep, working in the medial direction, following the posterior fossa dura to the level of the inferior petrosal sinus. This vascular structure in the dural lining marks the inferior and medial limit of the exposure. Complete removal of the petrous apex can be achieved by drilling bone beneath the trigeminal ganglion and nerve (Figure 4B and 4C). The microscope is necessarily angled parallel to the middle fossa floor at this juncture to better visualize inferior to the fifth nerve. The basic technique is to core out the central portion of the bone of the apex until a thin shell of cortical bone is left that can be fractured and removed piecemeal. Further optimization of the exposure can be attained on the lateral aspect by repositioning the microscope to view as perpendicular to the middle fossa floor as possible and removing bone under the cochlea to expose as wide an area of posterior fossa dura as possible.

Special mention is appropriate at this point of the particularly important concept of approach angle when this bone removal is performed in combination with another approach such as a frontotemporal or combined petrosal approach. Localization of the IAC in relation to the surface of the middle fossa floor depends on the angle of approach. When the approach is performed with the patient's head in a lateral position, the aforementioned orientation applies. However, when this technique is performed as part of a frontotemporal type of approach, the relative relationship of the IAC changes. The effect of approaching from more anterior is to diminish the angle between the IAC and the gspn. Furthermore, the IAC is relatively more perpendicular to the axis of view as opposed to parallel from the straight lateral orientation and is at a shallower angle away from the surgeon (Figure 5). In contrast, when this bone removal is performed as part of a combined petrosal approach, the viewing angle of the surgeon is shifted posterior. This has an opposite effect on the orientation of the IAC relative to the surgeon. The angle between the IAC and the superior semicircular canal is diminished, and the IAC is at a steeper angle away from the surgeon. This alteration in relationship of the IAC to the surgeon is critical knowledge when the bone removal is performed from an alternate approach angle.

Dural Opening

Proper handling of dural opening (Figure 6) is the next critical juncture in optimizing exposure with both the middle fossa and extended techniques. For the middle fossa approach, the initial dural incision is parallel and just inferior to the superior petrosal sinus. The second limb of the incision is parallel to the axis of the IAC over the posterior aspect of the canal to minimize the chance of injury to the facial nerve, which typically lies on the anterior side of the tumor in the case of a schwannoma. Before this incision, it is advisable to first electrically stimulate over the dura to help localize an unusual course of the facial nerve. The T-type incision creates 2 flaps that can be reflected to expose the IAC contents.

A primary goal of the extended middle fossa approach technique is avoidance of injury to the temporal lobe and preservation of venous structures. Incisions are made parallel to the superior petrosal sinus, both above and below. The superior petrosal sinus is then interrupted medially, taking care to avoid injuring the trigeminal nerve as it enters the Meckel cave at the porus trigeminus (see Video 3, Supplemental Digital Content 3, http://links.lww.com/NEU/A437, showing dural opening and tumor removal). The incision is then continued in the tentorium in the posterior direction approximately 1 cm. A suture is placed in the corner of the tentorium and used to retract the tentorium superiorly. This results in temporal lobe retraction under the protection of the tentorium. This will also avoid stretching or tearing any bridging vein structures from the inferior temporal lobe to the superior petrosal sinus such as the vein of Labbé. Now the dura is opened at the porus trigeminus and the trigeminal nerve is freed from the surrounding dural ring. Incisions can be made in the posterior fossa dura at the medial and lateral limits of exposure; the resulting dural flap can be displaced anterior into the cavity left by bone removal; or the dural flap can be removed altogether.

Intradural Dissection Technique

Nuances of Technique for Specific Lesions

Vestibular Schwannomas. The middle fossa approach is typically reserved for cases of purely intracanalicular vestibular schwannomas or those with a limited extension into the cerebellopontine angle not making contact with the brainstem. Tumors large enough to make contact with the brainstem can be done in this way; however, in my experience, the results of both functional preservation of hearing and the facial nerve have suffered.

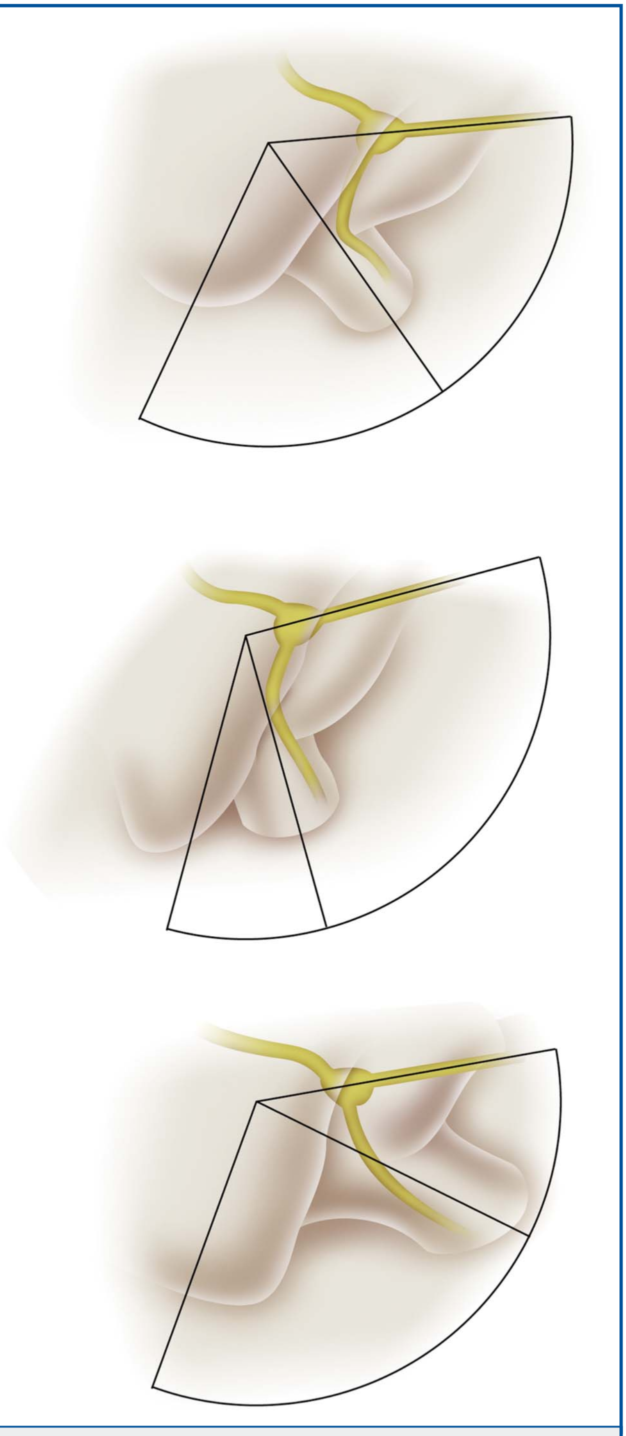

FIGURE 5. *The relative position of the internal auditory canal in relation to the angle of view from straight lateral (**top**), posterolateral (**middle**) as in a combined petrosal approach, and anterolateral (**bottom**) as seen from a frontotemporal approach. The figure is illustrated on the left side to match Figures 1 though 4. Adapted from: Day JD, Tschabitscher M.* Microsurgical Dissection of the Cranial Base. *New York, NY: Churchill Livingstone; 1996: appendix II, Figure 3.*[13]

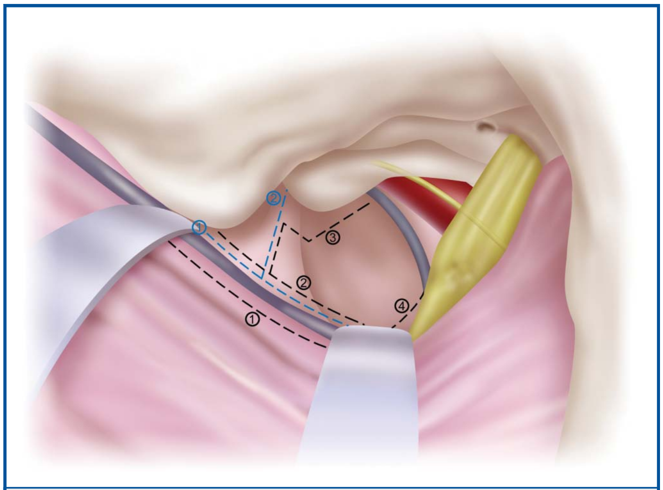

FIGURE 6. *The dural incisions are outlined for a middle fossa approach (blue dashed line) and extended middle fossa approach (black dashed line).*

The keys to successful removal of these small lesions are early identification of the facial nerve, adequate debulking of the mass in the canal to facilitate dissection, and medial-to-lateral dissection of the tumor from the facial and cochlear nerves. The facial nerve is identified both visually under high magnification and with a facial nerve stimulator at low intensity (ie, 0.5 mAmp). Debulking the mass gently with fine, sharp scissors and small pistol grip cup forceps facilitates mobility of the mass that is packed into the canal, making dissection easier. A fine angled dissector is an appropriate choice for developing the plane of dissection between tumor capsule and the nerves (facial and cochlear), working from medial to lateral. This medial-to-lateral technique helps to limit stretch and traction on the cochlear nerve at its fundal end where it enters the modiolus. The cochlear nerve splits into many fascicles to enter the tiny bony openings here and is thus fragile and most vulnerable to avulsion (see Video 3).

Also helpful in hearing preservation cases is direct monitoring of the cochlear nerve. Loss of amplitude or delay in signal should prompt the surgeon to quickly apply papaverine soaked into a small piece of Gelfoam to attempt to reverse ischemia caused by manipulation-induced spasm of the auditory artery. Otherwise, a slight modification in dissection technique or pressure is in order.

Medial Petrous/Petroclival Meningiomas. The extended middle fossa approach has been a solid choice in cases of small, medial petrous and petroclival tumors. Tumors falling within certain boundaries will be adequately exposed by the approach. The medial extent should be no more than falling between the midline of the clivus and the petroclival sulcus. Inferiorly, tumor should not extend below the bottom level of the IAC. The superior semicircular canal is the lateral limit of tumor extension. Beyond these boundaries, vision is very limited with this approach alone.

A primary advantage of the removal of petrous apical bone in meningioma cases is direct exposure of posterior fossa dura at the origin of the tumor, thus exposing the blood supply before significant tumor dissection. Tumor may also be dissected away without retraction of the cerebellum or brainstem. A primary consideration in these cases for the surgeon is to locate the abducens nerve. Generally, the nerve will be deflected in the medial and inferior direction as it courses to its entrance through a dural sleeve and into the Dorello canal. As tumor is debulked, the mass can be collapsed into the space created by the fenestration in the petrous apex, providing a view medial and inferior to locate the sixth nerve. Cautery is kept to a minimum in dissecting the medial and inferior portions of the tumor until the sixth nerve has been identified to avoid injury if the nerve courses through tumor.

Meningiomas in this location tend to maintain a good arachnoidal plane of separation between tumor and the seventh and eighth cranial nerves. Tumor can be delivered out of the IAC, working in a medial-to-lateral direction to avoid stretch on the cochlear nerve, just as in a vestibular schwannoma resection. The nerves tend to be displaced inferior and lateral in cases of meningioma and therefore can be difficult to see in the lateral depth of the exposure. Liberal use of the nerve stimulator to detect a stretched facial nerve is advisable.

Closure

The primary goal in closure is isolation of the subarachnoid space from the extradural compartment and eliminating any open connection to the air cells of the temporal bone. An excellent material to achieve these goals is adipose tissue. An adipose graft is harvested from the lower abdomen. The tissue is cut into thin strips for placement in the defect (see Video 3, showing dural opening, tumor removal, and closure). Whether closing after a middle fossa approach or extended approach, the method of laying strips of adipose tissue into the fenestration in the temporal bone is the same. Each strip is laid across the floor of the middle fossa with its medial end in the bone defect and its lateral end at the margin of the craniotomy. Before the adipose strips are laid, bone wax can be applied to any large open-air cells. If the tegmen tympani has been opened, the bone should be reconstructed with split-thickness calvarium, titanium mesh, or other rigid material to keep the graft from contacting the ossicles if exposed, thus dampening their movement. Moist pieces of Gelfoam may be used to augment the closure by supporting the lateral aspect of the fat strips against the dura and filling dead space. An alternative to adipose tissue is a pedicled vascularized muscle flap harvested from the posterior aspect of the temporalis muscle. Essentially, a strip of muscle is fashioned that can lie across the floor and fill the fenestration to achieve a seal with vascularized tissue. A drawback to this method is that it may cause pain with jaw movements postoperatively. This method of closure is useful to keep in mind in cases of infection.

The bone flap is replaced, securing it with titanium plates and screws. It is important to resuspend the temporalis muscle and fascia at the linea temporalis, whether by reattaching to a cuff left behind during opening or another method. This will prevent sagging of the muscle as it contracts postoperatively. A small round drain is helpful in the subgaleal plane to diminish the likelihood of subgaleal fluid collection after surgery. The drain is typically removed in 24 to 48 hours. Closure in this way obviates the need for a pressure dressing.

Postoperatively, patients are instructed to avoid anything that will increase the pressure in the Eustachian tubes for at least 6 weeks after surgery. Actions such as suppressing a sneeze or blowing open the Eustachian tubes by holding closed the nostrils and forcibly exhaling is not encouraged. These actions increase the pressure transiently in the nasopharynx and force air into the Eustachian tubes, which could dislodge the adipose graft and result in leakage of cerebrospinal fluid.

Potential Complication Management

Cerebrospinal Fluid Leaks. Cerebrospinal fluid leakage after surgery has been rare in my experience but has occurred. Leakage most commonly has been nasal, from the nostril on the side of the approach. The route of drainage is via the Eustachian tube into the nasopharynx. Even more rare is drainage at the incision line, which can be successfully treated by oversewing the wound. Cerebrospinal fluid rhinorrhea is first treated with lumbar spinal drainage. Drainage is performed continuously at a rate of 5 to 10 cm^3/h for 72 hours. The drain is then clamped and the patient is observed for the next 12 to 24 hours. If there is no further leakage, the drain is removed. Persistent leakage results in a return to the operating room to explore and augment the closure. Reocclusion of air cells and repacking with adipose tissue of the petrous defect are performed. Lumbar drainage is then continued postoperatively for at least 48 hours.

Middle Ear Entry. Opening the tegmen tympani to expose the middle ear space may be either incidental or purposeful. In any event, the tegmen must be reconstructed properly to avoid a conductive hearing loss or a CSF fistula. Placing adipose tissue, muscle, or the like into the middle ear space will contact the ossicles and result in a conductive deficit. Therefore, the preferred method is to place a fascial graft over the bony defect, one that is large enough to provide a good overlap at the defect margins. A solid structural graft such as split-thickness calvarium, titanium mesh, or other firm material is then placed over the fascial graft and the defect. Again, this structural graft is larger than the defect so that it will sit securely over the defect. The temporal dura will then press against the graft once retraction is relaxed to hold this in place. This can be augmented by adipose tissue between the dura and the structural graft for additional pressure.

Temporal Durotomy. In few other cranial base approaches does a durotomy harbor such potential for serious injury to the underlying brain. Because of the retraction forces applied to the temporal lobe under the dura, incidental durotomies can significantly affect the temporal lobe owing to herniation through the durotomy when the temporal dura is retracted. This injury can be disastrous for the patient, especially on the dominant side. Therefore, careful management is critical in this procedure.

I prefer to place an inlaid dural graft of collagen membrane to cover the exposed temporal lobe if this situation occurs. A lateral incision is made in the dura. The lobe is gently retracted upward, and the collagen sheet is placed over the brain tissue to completely overlap the durotomy margins. The lateral incision is then closed. This inlaid graft will then completely cover and protect the brain at the durotomy. It is not necessary to close the durotomy when managed in this way.

Internal Carotid Artery Injury. Certainly, the optimal management of this potential complication is avoiding it. Intimate knowledge of the anatomy, sufficient experience, and careful use of a diamond burr only around the artery are necessary elements of preventing injury. However, should this injury occur, specific actions must be kept in mind. Maintenance of normotension is critical to avoid insufficient collateral flow to the brain. A complete discussion of major arterial repair is outside the scope of this article. In brief, large defects are managed by either occlusion and sacrifice or direct repair. In the case of carotid injury in such cases, the procedure should be aborted, and the patient should be taken for immediate angiography and possible intervention if indicated by an endovascular specialist.

CONCLUSIONS

The middle fossa and extended middle fossa approaches are relatively uncommon procedures in neurosurgical practice used to access the cerebellopontine angle, petroclival area, and posterior cavernous sinus. These approaches can lead to a small and possibly inadequate exposure if not performed well and bone removal is not maximized. A number of nuances of technique exist that help to optimize the exposure obtained by these methods via maximizing bone removal and proper handling of the complex dural construction encountered in the region. Furthermore, understanding the limitations of these approach techniques will aid in proper approach selection for the lesion under consideration.

Disclosure

The author has no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENT

The anatomic details of extending the dural exposure to include elevation of the dura propria in middle fossa surgery are a critical step that is often ignored in most technical descriptions of this surgery. Any neurosurgeon participating in these procedures should review this report in detail.

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