35 Endoscopic Endonasal Transpterygoid Approaches to the Posterior Fossa

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Introduction

Endoscopic endonasal approaches (EEAs) to the skull base have become an important and more frequently utilized technique complementary to traditional open approaches to the skull base. With continued advances in surgical technique and technological developments, the use of EEA has expanded beyond the sagittal plane to pathologies along the coronal plane of the skull base. Coronal approaches are used to access pathologies lateral to the midline corridor and lateral to the carotid artery in the para-median and para-sagittal planes (Fig. 35.1a). The coronal plane approaches are divided into three different depths. The anterior coronal plane has an intimate relationship with the anterior fossa and obits, the middle coronal plane with the middle fossa and temporal lobe, and the posterior coronal plane with the posterior fossa [1]. The middle and posterior coronal planes can be further divided based on the relationship of the pathology to the horizontal petrous carotid artery (infra- and supra-petrous approaches) (Fig. 35.1a). These regions can be affected by a variety of pathologies including cholesterol granulomas, chondrosarcomas, chordomas, schwannomas, meningiomas, sinonasal tumors, and metastases [2]. The location and nature of the pathology relative to surrounding neurovascular structures are critical in the selection of the surgical approach. An EEA to these locations requires working around and potentially manipulating the internal carotid artery (ICA); therefore, anatomical knowledge of the ICA is imperative to minimize the risk of inadvertent damage. The ICA is divided into several segments at the anterior skull base: the paraclinoid, paraclival, lacerum, horizontal, and parapharyngeal segments with each segment associated with their respective skull base landmarks (Fig. 35.1b). In this chapter, we focus particularly on approaches to the posterior fossa including EEA to the petrous apex, petroclival junction, condyle, and jugular foramen. These anatomical modules share the same initial phases of dissection; an endoscopic endonasal transpterygoid approach is the initial step to gain access to structures in the posterior coronal plane.

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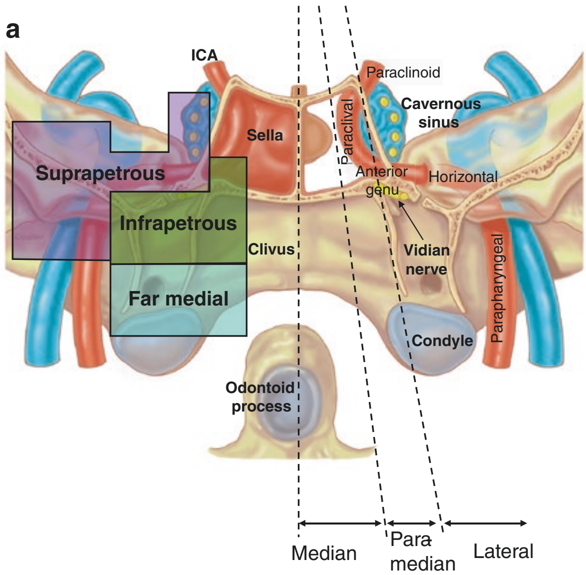

b

ICA segment	Anatomical landmark
Paraclinoid	Medial OCR
Anterior genu/foramen lacerum	Medial pterygoid wedge
Horizontal segment	Vidian nerve
Ascending/parapharyngeal	Eustachian tube

Fig. 35.1 (**a**) Schematic demonstrating the median, paramedian, and lateral coronal planes of the expanded endonasal endoscopic approach (EEA) (dotted lines) and suprapetrous, infrapetrous, and far medial approaches to the middle and posterior fossa (black boxes). (**b**) Table demonstrating relevant EEA skull base anatomical landmark to each segment of the internal carotid artery (ICA)

Preoperative Considerations

Detailed preoperative imaging is essential in planning and executing the appropriate surgical approach. High-resolution magnetic resonance imaging (MRI) and computed tomography (CT) are routinely obtained to evaluate the quality of the pathological lesion and its relationship to surrounding structures. CT scans can provide a detailed view of the bony anatomy relevant to the surgical approach and corridor including the paranasal sinuses, orbit, and skull base. We routinely also obtain CT angiography (CTA) to further delineate the relationship of the vasculature to the lesion and the bony landmarks, particularly, the course of the carotid arteries. Skull base MRI with and without intravenous contrast can provide further information on the relationship of the pathology to surrounding neural structures and soft tissue. We utilize the merging of these imaging modalities for use during the surgery for frameless stereotactic image guidance [3].

Vidian nerve sacrifice during transpterygoid approach is generally very well tolerated. Patients undergoing a transpterygoid approach should be questioned about symptoms of dry eye, ideally using the Dry Eye Questionnaire (DEQ-5) or even phenol red thread testing if indicated. Patients with significant dry eye symptoms preoperatively may suffer from moderate to severe dry eye after Vidian neurectomy [4]. Also, ophthalmic trigeminal (V1) dysfunction in addition to Vidian nerve deficit creates a very real risk of corneal keratopathy and should be considered in approach selection if pathology or resection could cause a V1 deficit.

Surgical Procedure

A dual-surgeon, four-handed technique with a skull base neurosurgeon and otolaryngologist team allows for best management of intranasal structures and a bimanual, binostril technique which allows the use of traditional two-handed microsurgical techniques while the second surgeon provides continuous endoscopic visualization of the surgical target. The surgeons are positioned on the right side of the patient opposite the anesthesia team. The surgical technician is positioned toward the foot of the bed allowing the surgeons unrestricted access to the midface.

Patient Positioning

After intubation, the patient is placed as close to the right edge of the operating room table as possible and is placed in a 3-pin Mayfield head holder. The patient is then positioned with the neck extended slightly, head rotated to the right by 15–20°, and the vertex tilted to the left if neck flexibility allows. Neurophysiological monitoring of cortical (SSEPs, somatosensory potentials) and brainstem (BAERs, brainstem auditory evoked responses) functions given dissection in close proximity to the internal carotid artery and posterior circulation. The nose is decongested with topical 0.05% oxymetazoline applied using ½ × 3 inch cottonoids. A povidone solution is applied to the midface and chlorhexidine to the periumbilical areas in preparation for potential autologous fat-graft harvest. If a large dural defect in the posterior fossa is anticipated, either thigh should be prepped and draped for fascia lata graft harvest.

The approach begins in the right naris. The middle turbinate, inferior turbinate, and nasal septum are identified. The nasal corridor is widened with lateralization and out fracturing of the inferior turbinate followed by resection of the middle turbinate that allows for increased space for the endoscope and the insertion and manipulation of instruments. Hemostasis can be obtained with electrocautery at the stump of the middle turbinate.

Nasoseptal Flap

At this point, vascularized nasoseptal flap is elevated on the side contralateral to the disease and is stored in the nasopharynx or maxillary sinus (if needed for lower clival tumors). The nasoseptal flap should be elevated contralateral to the side of disease, as during a transpterygoid approach one inevitably manipulates and often sacrifices the posterior nasal artery and sphenopalatine artery which supply the nasoseptal flap on the side of the disease. In rare cases where it must be placed on the side of disease, the flap pedicle can be widely mobilized into the pterygopalatine space, but this does risk the vascularity [5]. Monopolar electrocautery with an insulated tip is used to incise the nasal mucosa. The inferior cut is initiated at the choanae, progressing along the vomer, and is taken anteriorly where the septum meets the nasal floor to the anterior head of the inferior turbinate. This can be extended to include the nasal floor for larger clival/petroclival lesions [6]. The superior incision is made at the level of the sphenoid os rostrally and is extended anteriorly along the visible superior septum to the head of the middle turbinate approximately 1 cm below the skull base to allow for preservation of the olfactory epithelium and function. Once the head of the middle turbinate is reached, the incision is taken superiorly to the nasal vault and then brought anteriorly along the septum to the mucocutaneous junction to join with the inferior incision (Fig. 35.2). The size of the flap is planned according to the anticipated surgical defect. The mucoperichondrium is elevated using a Cottle dissector in an anterior to posterior fashion after ensuring that all of the incisions have been carried out through the periosteum and perichon-

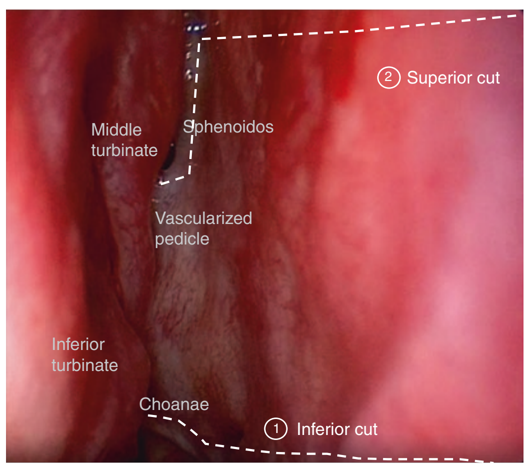

Fig. 35.2 Creation of expanded vascularized nasoseptal flap with dotted lines outlining the inferior and superior cuts that are taken anteriorly to the anterior head of the inferior turbinate (out of the frame of this figure)

drium. The nasoseptal flap is then stored in the nasopharynx or maxillary sinus until the reconstructive phase of the surgery.

Nasal Septectomy and Bilateral Sphenoidotomies

The posterior limb of the contralateral nasoseptal flap pedicle is transected proximally and freed from the posterior septum. A posterior nasal septectomy is performed to allow rotation of this posterior mucosa anteriorly to cover the septal cartilage exposed by flap harvest [7]. This is sutured to the septum and nasal protective sleeves put in place [8]. Wide bilateral sphenoidotomies are completed to allow for a wide nasal working corridor. The natural sphenoid ostium is identified and enlarged using Kerrison rongeurs or the rostrum fractured and removed. A wide sphenoidectomy is performed with removal of the rostrum using a surgical drill. This is extended laterally to the level of the medial pterygoid plates and the lateral wall of the sphenoid sinus, superiorly to the level of the planum sphenoidale, and inferiorly to the floor of the sphenoid sinus. Septations within the sphenoid sinus are then removed, completing the sphenoidotomies providing bilateral nasal access, visualization of key structures, and access for three/four-handed surgical technique (Fig. 35.3).

Maxillary Antrostomy and Exposure of Pterygopalatine Fossa

Next, the uncinate process and the natural ostium of the maxillary sinus are identified. A maxillary ostium seeker can be used to carefully displace the free edge of the uncinate process outwardly and anteriorly. Upbiting forceps are used to carefully grasp the free edge of the uncinate process to perform the uncinectomy taking care to not damage the lamina papryacea. Once the uncinate

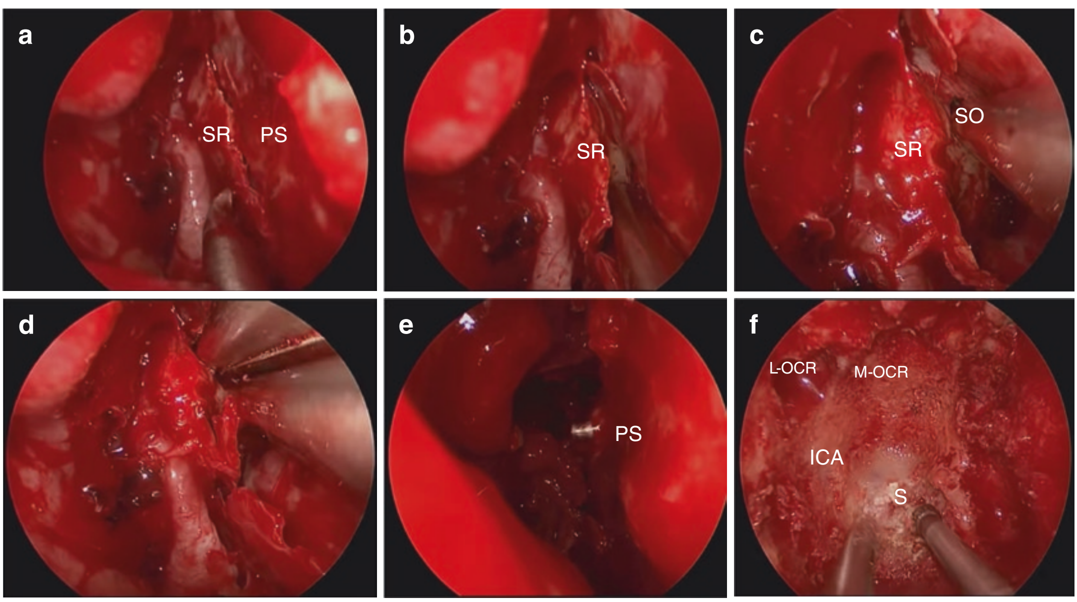

Fig. 35.3 (**a**) The posterior septum (PS) is disarticulated from the sphenoid rostrum (SR) with a Cottle instrument. (**b**) The sphenoid rostrum (SR) is subsequently identified by stripping off the septal mucosa on the contralateral side. (**c**) The sphenoid os (SO) is identified and widened. (**d**) The sphenoid rostrum is removed and sphenoid sinus exposed with combination of Kerrison rongeur and drill. (**e**) 1–2 cm of the posterior septum (PS) is removed using a back biter after creating a reverse flap. (**f**) Completion of posterior septectomy and bilateral sphenoidectomy allowing for identification of key landmarks including the lateral opticocarotid recess (L-OCR), medial opticocarotid recess (M-OCR), internal carotid artery (ICA), and sella (S)

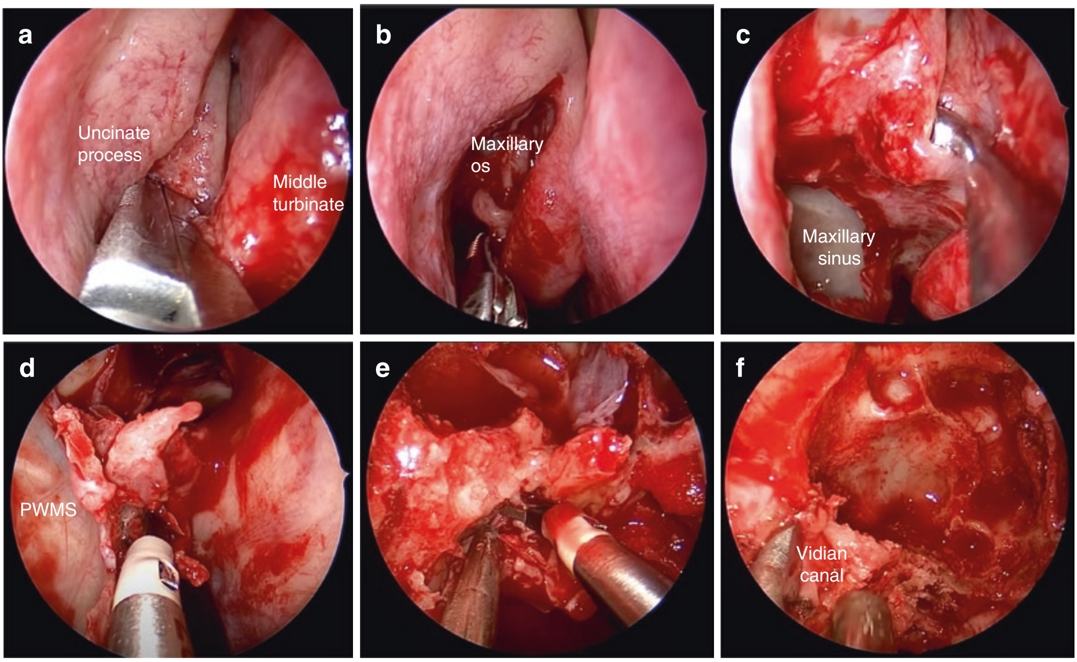

Fig. 35.4 (**a**) The uncinate process is identified and taken down to reveal the (**b**) natural ostium of the maxillary sinus. (**c**) The maxillary ostium is widened to complete the maxillary antrostomy. (**d**) The posterior wall of the maxillary sinus (PWMS) is visualized. The sphenopalatine artery is identified and coagulated. (**e**) The posterior wall of the maxillary sinus is removed to reveal the contents of the pterygopalatine fossa. The palatosphenoidal artery is coagulated and ligated. (**f**) Further drilling and dissection of the posterior wall of the PPF reveals the Vidian canal

process is fully removed, the full maxillary ostium is visualized. The ostium is widened posteriorly using through-cutting forceps until the posterior wall is reached completing the antrostomy. The crista ethmoidalis is identified just posterior to the posterior wall of the maxillary sinus and the sphenopalatine artery is then coagulated with bipolar cauterization and sharply incised. The posterior wall of the maxillary sinus is then removed using Kerrison rongeurs in a medial to lateral fashion to the edge of the infraorbital nerve, careful to leave the periosteum intact, keeping the fat content in the PPF contained. The soft contents of the PPF are then identified at the level of the sphenopalatine foramen and displaced laterally to identify the palatosphenoidal vessels just lateral to the anterior boundary of the sphenoid process of the palatine bone. The terminal vessels of the palatovaginal canal are coagulated using endoscopic bipolar forceps and transected, which allows for subsequent lateralization of the contents within the PPF and identification of the medial pterygoid wedge and Vidian canal [9]. Subperiosteal dissection of the posterior wall of the PPF is carried out laterally until the Vidian canal is visualized (Fig. 35.4).

Drilling of the Vidian Canal and Identification of Horizontal ICA

The identification of the Vidian canal is critical to proceeding with coronal plane modules to the middle and posterior fossa as it allows for the safe identification of the junction between the horizontal petrous ICA and the vertical paraclival ICA at the level of the foramen lacerum [10]. Indeed, the "pterygoid wedge" (the wedge formed by the floor of the sphenoid meeting the medial pterygoid plate) is directly in line with foramen lacerum. The Vidian nerve can typically be identified at the base of this wedge and will track lateral to foramen lacerum to cross over the horizontal petrous ICA [10]. Image guidance can be used to verify the depth and location of the Vidian canal. As the Vidian nerve is still in its canal, it tethers the entire content of the PPF, therefore, preventing complete lateralization of its contents. The Vidian nerve can be preserved for the most medial approaches (petrous apex), but if full ICA control or lateralization is needed, Vidian sacrifice provides full access to the base of the pterygoid by allowing mobilization of the PPF contents laterally to the level of the descending palatine nerve. The sphenoid floor, pterygoid wedge and/or pterygoid base can then be drilled as needed. Even if the Vidian nerve is sacrificed, its stump should be preserved to maintain orientation once the wedge is gone.

Following a transmaxillary transpterygoid exposure, the following steps and technical modules can be completed to access specific regions of the posterior fossa as needed for the exact location of the lesion.

Petrous Apex

A transclival approach can be extended laterally to the medial petrous apex immediately deep to the paraclival ICA [11] (Fig. 35.1a). Pathologies common to this region include cholesterol granuloma, chondrosarcoma, petroclival meningiomas, and some chordomas. An EEA to lesions in this region is particularly favorable for extradural lesions that have remodeled the bony anatomy expanding the petrous apex medially, leading to intrusion of the lesion into the sphenoid sinus allowing access via a simple lateral extension of the transclival approach. However, when the disease extends more laterally, lateralization of the paraclival ICA is needed to access the lesion. Once the ICA has been identified and exposed at the foramen lacerum, it can be lateralized by removing all of the bone overlying the paraclival ICA from the sellar floor to foramen lacerum. Additional bone removal lateral to the ICA, including the lingual process, allows for further mobilization. The landmarks for access to the petrous apex form the medial petrous triangle (Gardner's triangle): anteriorly, the paraclival carotid artery; superiorly, the sixth nerve; and inferiorly, the petroclival fissure (Fig. 35.5). The most relevant anatomy for this approach includes the ICA and the sixth nerve (Video 35.1).

Infrapetrous Approach

For lesions inferior to the horizontal segment of the petrous ICA, a transpterygoid "infrapetrous" approach (so named for its relationship to the horizontal ICA) can provide access to these more caudally located lesions at or below the petro-

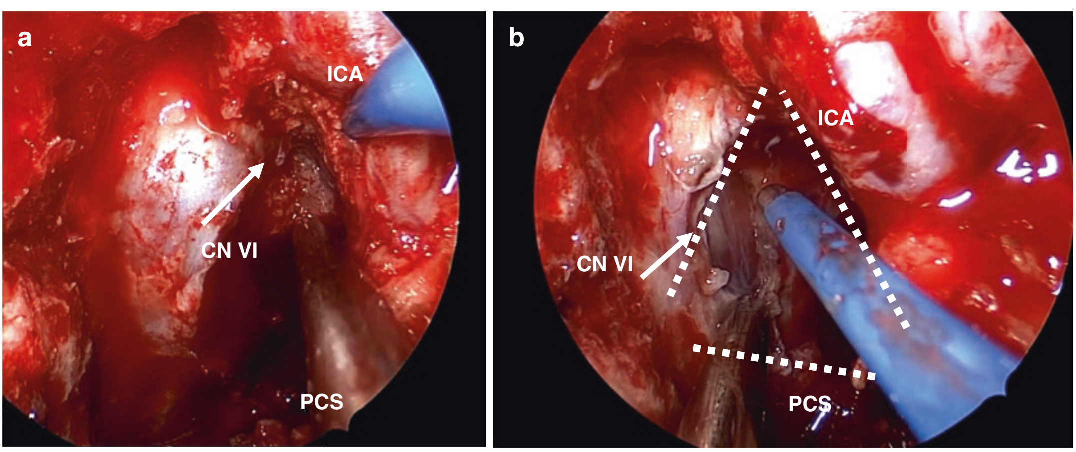

Fig. 35.5 (**a**) View of approach to petrous apex via a contralateral transmaxillary (CTM) approach for a chondrosarcoma. (**b**) Access to the petrous apex via the medial petrous (Gardner's) triangle, bounded by cranial nerve VI (CN VI) superiorly, paraclival carotid artery (ICA) anteriorly, and the petroclival synchondrosis (PCS) inferiorly

clival synchondrosis. Pathologies typical to this region include chondrosarcomas, chordomas, jugular tubercle, and petroclival meningiomas. This approach is frequently combined with a transclival approach to allow for a wider working angle. This approach requires the completion of the transpterygoid approach as described above as well as dissection of the eustachian tube (ET) at the foramen lacerum [1, 12]. After the identification and lateralization of the Vidian nerve, the pterygopalatine tissue is dissected and the medial and lateral pterygoid plates are drilled with a high-speed drill until they are flush with the foramen rotundum and foramen ovale, respectively, if necessary. The lacerum ICA is then identified by skeletonizing the inferior paraclival ICA. Once the ICA is identified at the foramen lacerum, to further facilitate mobilization of the ICA, the petrolingual ligament is sharply transected and the pharyngobasilar fascia at the anterior genu of the ICA and the fibrocartilaginous tissue along the inferior portion of the foramen lacerum is freed and removed to detach the ET laterally providing access to the inferior petrous apex and the inferior aspect of the petroclival fissure (Fig. 35.6) [13].

Jugular Foramen/Transcondylar/Hypoglossal Canal Approaches

Pathologies in this region include schwannomas, invasive carcinomas, paragangliomas, craniocervical junction chordomas, and meningiomas. The ET is an important landmark to identify and understand during this approach as it allows for the determination of the position of the parapharyngeal ICA [13]. While mobilization of the ET allows access to the inferior petrous apex as described in the previous section, further inferior exposure along the infrapetrous zone may require transection of the cartilaginous segment of the ET. As previously described, the dissection of the ET begins along the fibrocartilaginous tissue at the foramen lacerum. After sharp ligation of the petrolingual ligament, the connection between the ET and lacerum ICA can be transected to mobilize it inferolaterally. The tensor veli palitini can then be identified and released at the lateral surface of the ET and the levator veli palitini muscle can be released along the inferior surface of the ET. After mobilization of the ET tube along the superior, lateral, and inferior border, the ET can be transected by performing one cut at the lacerum segment and a second cut at the nasopharyngeal segment. This allows for wide exposure of the sublacerum corridor and provides access to the entire petroclival region and the underlying parapharyngeal ICA [14]. More recently, an alternative to ET transection has been proposed consisting of an anterolateral mobilization strategy in an effort to minimize the sequalae associated with ET transection [15]. Depending on the location of the pathology and extent of the required exposure, after mobilization or transection of the ET, a "far-medial" transclival approach can be utilized for drilling of the bone from the

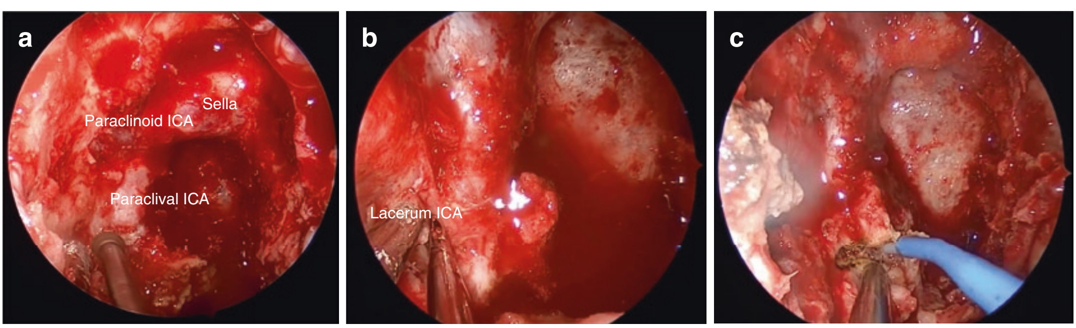

Fig. 35.6 (**a**, **b**) The bone over the paraclinoid, paraclival, and lacerum ICA are drilled and removed to facilitate mobilization of the ICA. (**c**) Once the ICA is identified at the foramen lacerum, the pharyngobasilar fascia and fibrocartilaginous tissue along the inferior portion of the foramen lacerum is carefully transected to detach the eustachian tube (ET) providing access to the right inferior petrous apex

petroclival synchondrosis to the condyle [16–18]. In brief, the nasopharyngeal mucosa is removed, revealing the prevertebral muscles. These longus and rectus colli muscles are subsequently resected to reveal the lower clivus, anterior margin of the foramen magnum, and the atlanto-occipital joint. If possible, the mucosa, muscles, and basopharyngeal fascia should be dissected together as an inverted "U-shaped" rhinopharyngeal flap [19]. This flap, supplied by the ascending pharyngeal arteries, helps separate the nasopharynx and oropharynx and provides important vascularized reconstruction tissue for lower clival or craniocervical junction tumors. The far-medial transclival approach, with transpterygoid jugular tubercle and transcondylar approach, is a natural lateral extension from the foramen magnum to the occipital condyles. The hypoglossal canal separates the jugular tubercle from the condyle and can be localized at the attachment of the colli muscles on the ridge of the supracondylar groove. The jugular tubercle can be drilled up to the inferior petrosal sinus without disrupting any neural structures. At least 50% of the medial occipital condyle can be drilled to provide access to the hypoglossal canal without causing instability [20]. Care should be taken when drilling the occipital condyle to avoid damage to the hypoglossal nerve and to not disrupt the synovial joint.

The parapharyngeal space can be dissected in cases with tumor involvement up to the parapharyngeal ICA. The ET again is a key landmark in this approach as it enters the petrous bone just medial to the ascending parapharyngeal ICA. Therefore, following the ET laterally allows for the identification of the ICA and the jugular foramen is directly lateral and posterior to the ICA. Cranial nerves IX, X, and XI are between the ICA and the jugular vein. In order to get lateral access to the ICA, a wide ipsilateral anterior and medial maxillectomy in addition to previously described maxillary antrostomy is often required to obtain greater access to the pterygomaxillary fissure, PPF, and infratemporal fossa. In general, this area is a borderline limitation for endoscopic endonasal approaches as proximal ICA control is difficult or impossible. These approaches can often be supplemented with a limited endoscopic transcervical dissection to provide proximal control and tissue dissection up to the skull base.

Contralateral Transmaxillary Approach

A recently introduced, alternative approach for lateral access beyond the posterior fossa from the cavernous sinus to the condyle is the contralateral transmaxillary approach that minimizes the need to manipulate the ICA. This approach utilizes a corridor via anterior maxillary antrostomy and medial maxillectomy on the side opposite the pathology. This provides a wider angle to the petrous apex, nearly parallel to the horizontal petrous ICA, that dramatically improves lateral access. Caldwell-Luc osteotomies and medial maxillectomy are maximized to allow introduction and manipulation of instruments including a drill through the transmaxillary corridor allowing access to areas of the petrous apex posterior and lateral to the paraclival ICA that are not accessible by the endonasal route without extensive dissection and mobilization of the ICA [21–23] (Fig. 35.7, Video 35.1).

Reconstruction

A multi-layer reconstruction covered with a vascularized nasoseptal flap harvested at the beginning of the surgical procedure is preferred for reconstruction. This flap should be in contact with the underlying reconstruction materials (fascia and/or fat) or demucosalized bone for appropriate healing. Deep layers in the posterior fossa include an inlay subdural graft of collagen matrix, a large epidural fascia lata onlay, and fat graft to bolster the onlay or fill in deep cavities such as the petrous apex when necessary. It is important to not leave any foreign body, tissue glue or other nonvascularized tissue between the flap and these deeper layers which are sandwiched over the defect edge (Fig. 35.8).

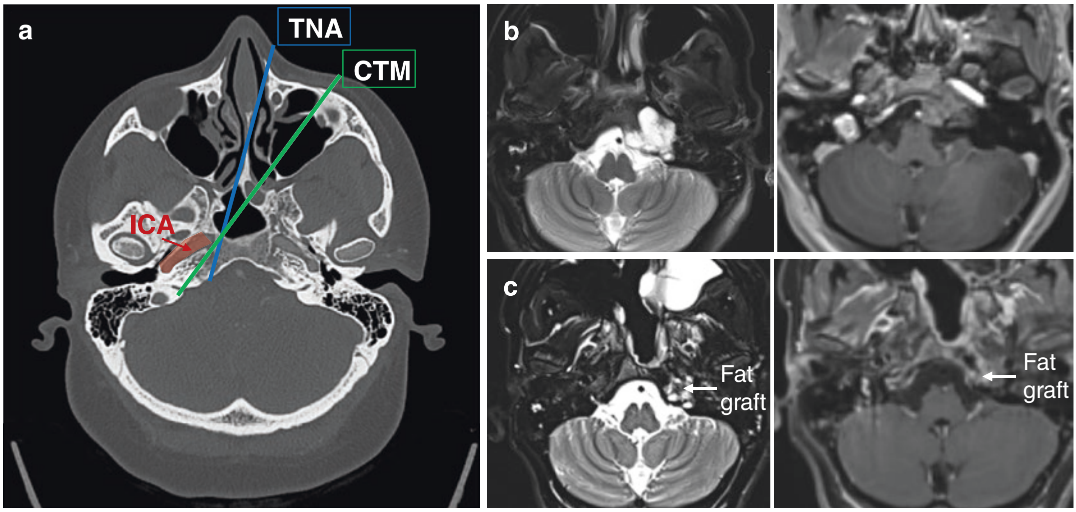

Fig. 35.7 (**a**) Computed tomography angiography (CTA) demonstrating the improvement in the angle of approach to the petrous apex relative to the horizontal petrous internal carotid artery (ICA) with the contralateral transmaxillary approach (CTM) compared to traditional transnasal approach (TNA). (**b**) Magnetic resonance imaging (MRI) of a right petrous apex chondrosarcoma, T2 axial sequence (left), T1 post-gadolinium contrast (right). (**c**) Postoperative MRI demonstrating complete resection of petroclival chondrosarcoma through CTM, T2 axial sequence (left), T1 post-contrast (right)

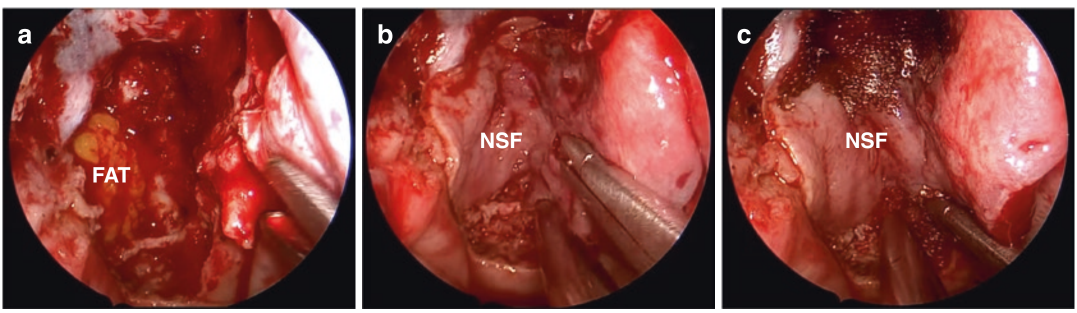

Fig. 35.8 (**a**) A fat graft to cover any dead space remaining from surgical resection. (**b**) The nasoseptal flap (NSF) is rotated to cover the skull base defect. (**c**) Surgicel is placed on top to hold the nasoseptal flap (NSF) in place

Postoperative Management

General principles of managing CSF leak and CSF fistula are followed postoperatively. Patients are advised to minimize maneuvers that increase intracranial pressure such as coughing, sneezing, and straining. It is critical, however, that they not be kept on the bed rest and head of bed elevation greater than 30° is maintained at all times to ensure lower intracranial pressure. Third-generation cephalosporins are administered until the nasal packing is removed to minimize the risk of meningitis. A lumbar drain should be used when a high-flow CSF leak/dural defect in the posterior fossa is encountered intra-operatively and has been shown to dramatically reduce postoperative CSF leak in this setting in a randomized controlled trial [24]. Nasal packing, if present, is removed 5–7 days after surgery and septal splints are removed around 1–2 weeks postoperatively. The patient is advised to irrigate the nasal cavity with normal saline and the nasal cavity is debrided in the office every 2–3 weeks until crusting stops.

Functional Preservation Strategy

Functional preservation is largely determined by the appropriate surgical approach selection and complication avoidance and management.

Complications

In addition to general morbidities associated with an endonasal approach such as nasal flap necrosis, nasal crusting, and recurrent sinusitis, the transpterygoid approach can lead to specific potential morbidities associated with manipulation and damage to relevant neurovascular structures including (1) dry or uncomfortable eye from division of the Vidian nerve, especially in patients with pre-existing dry eye or V1 dysfunction (2) secretory otitis media and conductive hearing loss from transection of the ET and (3) palatal numbness from damage to the descending palatal branch of the fifth nerve [4, 25, 26]. More severely, complications related to intradural damage, cranial nerve injury, and cerebrovascular stroke secondary to ICA damage are more rare but real complications related to these approaches. Coronal plane approaches such as these (level IV and V) have a significantly higher risk of complications, longer surgical times, and increased length of stay [27]. However, in a series published by Zanation et al. who reviewed 20 cases of endoscopically resected petrous apex lesions, no carotid artery or cranial nerve injuries were reported [12] and in another series of 9 patients published by Hofstetter et al., the authors reported no vascular or cranial nerve injuries for transpterygoid approaches to the PPF, petrous apex, and Meckel's cave [28]. A systematic review of surgical outcomes after endoscopic management of cholesterol granulomas of the petrous apex reported comparable outcomes with the EEA compared with lateral approaches, with the endonasal route carrying a lower morbidity rate [29]. Filho et al. recently reviewed 26 patients reported in ten articles who underwent EEA resection of skull base chondrosarcomas and found that complications were few, with 2 patients presenting with CSF leaks, one patient with cranial nerve palsy, and no vascular-related injuries [12, 30–39].

Selection of Approach

Surgical approach selection to tumors of the posterior fossa depends on a multitude of factors as each approach has its inherent risks to the surrounding brain parenchyma and neurovascular structures. The location and anatomic relationships of the tumor are key determinants on whether a lesion is favorable or not to be tackled from an EEA approach. In general, tumors which originate medial to cranial nerves are best approached via a medial or endonasal approach. In addition, lesions that have created a window by expanding the medial petrous triangle toward the clivus or lesions with medial expansion into a well-pneumatized sphenoid sinus may place the majority of the lesion medial to or accessible behind the vertical segment of the ICA, making the anterior EEA approach a favorable approach with low complication risks. For lesions more lateral to the ICA, especially extradural tumors along the inferior edge of the petrous ICA, the transpterygoid approach may be appropriate. Intradural lesions such as meningiomas and schwannomas are more challenging, but the same anatomic rules apply (relationship of tumor medial to neurovascular structures). Approach selection for these tumors may depend more on surgeon experience and team learning curve with EEA reserved for the most experienced surgical teams, able to manage vascular injury and complex cranial base reconstruction [40].

The primary contraindication to these endonasal approaches is location of critical neurovascular structures medial or ventral to the lesion, requiring significant manipulation during exposure and dissection. For example, medially extending vestibular schwannomas are a contraindication to EEA given the ventral location of the facial nerve relative to the tumor. Jugular foramen tumors also typically displace the lower cranial nerves medially given the medial location of the pars nervosa. Tumor size, vascularity, fibrosis, or calcification are not specific contraindications to these approaches, but they may dramatically increase the difficulty and overall resectability. As such, surgeon experience is a key factor when considering the use of these approaches (or any approach). The categorization of EEA approaches into five levels of difficulty with increasing complexity and learning curve separates the coronal planes approaches such as an intradural transpterygoid approach into the most advanced procedures that fall under level V [41]. These approaches have the highest complication rates and should only be attempted after the skull base surgical team has developed experience with lower-level approaches and mastered the complex anatomy and reconstruction of the skull base [27]. Ultimately, the best decision of treatment and surgical approach should be determined in a multidisciplinary setting by encompassing the overall goals of surgery, natural history of the disease, patient co-morbidities and desires, and surgeon experience.

Conclusion

It is important to recognize that anteromedial transpetrous EEAs do not stand in competition with open transpetrosal approaches, but rather they are complementary. An anterior transpetrosal approach would provide superb access to the petrous apex but less so to the petrous base and the endoscopic endonasal transpterygoid or CTM approaches the inverse. This same complementarity holds true for a “far medial” approach to the jugular tubercle and/or occipital condyle in comparison to a far lateral approach. Recognizing this and acquiring facility in both open and endonasal approaches should be the ultimate goal of every skull base surgeon.

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