Endoscopic approaches to the cavernous sinus

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Skull base tumors that involve the cavernous sinus (CS) present a challenge to the endoscopic surgeon. Most such lesions arise from sellar pathology that involves the medial wall of the CS, which can be accessed by a transsphenoidal transsellar approach. Tumors that arise primarily in the medial CS may be accessed via a transtentorial transsphenoidal parasellar approach, which avoids the dissection of sellar contents but requires the removal of bone overlying the carotid artery. Involvement of the tumor in the lateral CS may be accessed by a transmaxillary transpterygoid approach in patients who wish to avoid a craniotomy and in whom radiosurgery is not an option. These tumors are associated with a greater risk of cranial nerve injury, including extraocular palsy. Important adjuncts to the endoscopic approach include angled instrumentation, neuronavigation, intraoperative Doppler and intrathecal fluorescein injection. Tumor extirpation from the CS and cytoreduction are realistic goals for the endoscopic surgeon in well-selected cases.

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The cavernous sinus (CS) is a paired structure that is part of the system of intracranial venous sinuses that run within the dura mater.1 The contents of the CS include the internal carotid artery (ICA), the sympathetic plexus, the 3rd, 4th, and 6th cranial nerves (CN); the first and second divisions of the trigeminal nerve (V1 and V2); and multiple venous tributaries and spaces. The ICA forms a siphon that divides the CS into lateral and medial compartments.2 The lateral compartment contains neural structures, whereas the medial compartment is largely empty. The medial wall faces the sella turcica and pituitary gland, whereas the anterior edge borders the superior orbital fissure. The anterior and medial aspects of the CS share a variable common wall with the sphenoid sinus depending on the pneumatization pattern of the sphenoid bone.3

The CS has been traditionally approached by a transcranial route in which the lateral wall of the CS is entered first.4 The presence of CN within the lateral CS raise significant concerns for postoperative CN palsy and inadequate tumor resection, especially when the lesion of interest lies within the medial compartment of the CS. Although postoperative radiosurgery can be used to control residual tumor within the CS, the risks of hypopituitarism and optic neuropathy limit the maximum dose. Approaches to the CS at the ventral skull base have been explored that provide more direct access to the medial CS and avoid the need for craniotomy in selected patients.5,6

Through our experience with a wide range of pathology and clinical scenarios, a role has emerged for 3 distinct endoscopic approaches to the CS (Figure 1). These approaches are derived from the 4 endoscopic corridors that have been previously described.7 The transsphenoidal transsellar approach provides direct access to the sella and may be extended to expose the medial wall of the CS. The transtentorial transsphenoidal parasellar approach allows direct access to the anterior face of the CS through the lateral sphenoid sinus. The transmaxillary transpterygoid approach extends the lateral exposure to address lesions within the lateral compartment of the CS. The application of a particular ap
The approach is determined by the clinical scenario as well as the ability of the operating surgeon.

**Indications**

A variety of benign and malignant pathology can involve the CS. The most frequently encountered scenario is invasion of the medial wall of the CS by a pituitary adenoma (Figure 2). Clival chordomas frequently extend into the parasellar region and may invade the CS (Figure 3). Primary tumors arising within the CS are rare and include lymphoma, hemangioma, hemangiopericytoma, and chondrosarcoma. The presence and extent of CS invasion should be defined during surgical planning. The Knosp-Steiner classification provides a useful determination of the extent of tumor invasion relative to the carotid artery (Figure 4). If complete tumor resection is a surgical goal, the presence of tumor within the lateral CS may indicate...
a transpterygoid approach for lateral exposure. Conversely, if CS involvement is limited to the medial compartment, or if the surgical goal is biopsy or debulking, the selection of a less invasive, more medial approach may be appropriate depending on the pathology.

**Technique**

Each approach begins with preparation of the nasal cavity with topical application of 4% cocaine on cottonoid pledges for 10 minutes. A lumbar puncture or lumbar drain is performed preoperatively and intrathecal fluorescein is administered to assist with detection of intraoperative cerebrospinal fluid (CSF) leak. The patient’s head is secured with pins in a Mayfield bracket to facilitate stability and accurate intraoperative neuronavigation (BrainLab, Inc, Westchester, IL). Magnetic resonance imaging (MRI) coregistered with computed tomography angiography is useful to delineate the extent of tumor and its relationship with the carotid artery. After the patient is draped, a 0-degree endoscope is used to inspect the nasal cavity. Local injection of 1% lidocaine with 1:100,000 epinephrine is performed of the sphenopalatine foramen, uncinate process, vertical lamella of the middle turbinate, and bilateral mucoperichondrial septal flaps. A posterior septectomy is performed to permit a 2-nostril, 4-handed surgical technique and greater maneuverability of surgical instruments.

The transsphenoidal transsellar approach to the CS has substantial overlap with the endoscopic approach for resection of pituitary tumors as previously described. This approach is usually selected for the management of a pituitary adenoma that has invaded the medial CS. A bilateral sphenoidotomy is performed and enlarged to produce a single midline corridor with direct exposure of the medial opticocarotid recesses on either side of the sella. The bone is opened over the sella and extended over the CS and the Doppler probe is used to locate the precise location of the carotid artery. After opening the dura just to the margin of the carotid and exposing the contents of the sella, a biopsy is taken and tumor removal begins by internal decompression. Once the sellar component has been resected, the lateral wall of the sella is explored with the use of an angled ring curette bent in a “hockey-stick” configuration. Often, a defect is encountered on the basis of palpation alone that indicates the site of CS invasion. Switching to a 30° angled endoscope allows the visualization beyond the edge of the sellar opening to identify residual tumor within the CS (Figure 5). Because the bone has been removed over the CS, the carotid can be gently retracted laterally to increase the exposure. Once the tumor has been resected, increased venous bleeding may be encountered, which usually responds to application of thrombin-soaked gelfoam. This approach can be extended superiorly by removal of the tuberculum sella and inferiorly by removal of the upper clivus.

The transethmoidal transsphenoidal parasellar approach to the CS provides direct access to the medial CS without opening the sella. This approach is useful for pathology arising primarily in the medial CS, and may be carried out entirely using a 0-degree endoscope. A total anterior and posterior ethmoidectomy is required, including uncinctomy, resection of the ethmoid bulla and retrobullar cells, and exposure of the lamina papyracea and fovea ethmoidalis as surgical landmarks. A transethmoidal sphenoidotomy is performed low and medial and is enlarged to include the natural sphenoid ostium by partial resection of the superior turbinate. The carotid prominence is then visible on the posterior wall of the sphenoid sinus, defined by the medial and lateral optico-carotid recesses (Figure 6).

Doppler is used frequently during the dissection to define the course of the intracavernous ICA (Figure 7). The sphenoid sinus mucosa is incised medial to the carotid prominence, to avoid injury in the presence of a dehiscent carotid canal. The mucosa is then reflected laterally. Bone removal over the carotid siphon can be performed with the use of a high-speed drill with a diamond burr and also with a Kerrison rongeurs (Figure 8). The exposed dura is then entered medial to the ICA with a retractable sickle knife. Biopsy and tumor removal are performed with angled ring curettes. Powered instrumentation should be avoided in proximity to the ICA.

The transmaxillary transpterygoid approach is appropriately used to gain exposure to lesions of the lateral CS. A wide opening of the maxillary antrum at the infundibulum is created with Kerrison rongeurs and Grunwald forceps. After exposure of the crista ethmoidalis and sphenopalatine foramen, the mucosa is removed from the posterior wall of the maxillary sinus. The sphenopalatine artery is isolated, cauterized with bipolar forceps, and divided. The orbital process of the palatine bone is removed with a high-speed drill, and a Kerrison rongeur is used to remove the posterior
maxillary sinus wall. Total ethmoidectomy and sphenoidotomy are performed as with the transethmoidal transsphenoidal parasellar approach. The outline of the vidian canal may be identified on the floor of the sphenoid sinus, and careful drilling anteriorly along the superiomedial surface of the canal allows preservation of the nerve and associated sphenopalatine ganglion (Figure 9). Drilling posteriorly
along this same tract leads to the petrous ICA and the foramen lacerum, which lie below the level of the CS. The sphenoid sinus mucosa is then removed, and bone removal over the anterior CS proceeds as described previously. Once the CS is entered, the abducens nerve may be identified coursing lateral to the carotid artery, and care must be taken to avoid excessive manipulation. The remaining CN run within the lateral wall and are less prone to direct injury. Reconstruction of the skull base defect after the tumor is removed depends on the approach selected and the extent of dural entry. Defects resulting from the transsphenoidal transsellar approach range from minor diaphragmatic weeping to large openings in to the suprasellar cistern, and multilayer reconstruction is the rule. In contrast, the transthyroidal transsphenoidal parasellar approach typically opens only the dura of the anterior CS, and the application of hemostatic agents such as FloSeal (Baxter, Deerfield, IL) may be sufficient closure. Defects resulting from the transmaxillary transpterygoid approach may extend far laterally into the pneumatized sphenoid bone, which predisposes to postoperative CSF leak if closure is not adequate. In these instances, a multilayer closure including a vascularized flap may be advisable. In all cases with substantial venous bleeding, the addition of intrathecal fluorescein as a surgical adjunct may significantly improve the surgeon’s confidence in detecting an intraoperative CSF leak.

Complications

The risks associated with all endonasal procedure should be considered for these approaches, including sinusitis, crusting, synechiae, epistaxis, vestibular burns, and orbital injury. Postoperative CSF leak may be encountered with any approach, particularly the transsellar approach when large dural opening is present, or in the transpterygoid approach when an occult dural entry goes unappreciated. The most serious complications are vascular in nature, and often occur intraoperatively. Focal venous bleeding is generally controlled with pressure and hemostatic agents, while low-flow arterial bleeding requires control with bipolar cautery. High-flow arterial bleeding may require immediate embolization for definitive control. Direct injury to the ICA carries a high risk of stroke, although sacrifice may be avoided with the timely application of a covered stent by a neurointerventional radiologist. Pseudoaneurysm and dissection of the ICA are additional considerations when the presentation of a cardiovascular event is delayed. The risk of CN injury is increased when dissection involves the lateral CS. The abducens nerve is particularly vulnerable because of its more medial course through the lumen of the CS, whereas the other CNs are relatively sheltered within the lateral wall of the CS. Although dissection of the medial CS theoretically carries decreased risk of CN injury, direct visualization of the area of dissection will help to prevent inadvertent blunt injury or retraction of the neural structures.

Discussion

The endoscopic approaches to the CS can be applied to a wide range of clinical scenarios where surgical management of skull base tumors is indicated. A team approach between the neurosurgeon and the rhinologic skull base surgeon is essential to defining surgical goals, maximizing exposure, and anticipating reconstructive needs. The decision to attempt tumor removal from the CS should be informed by a close examination of the preoperative MRI with the use of predefined criteria, such as the Knosp-Steiner classification. In addition, the age of the patient, consistency of the tumor, and its natural history must be considered. Soft tumors in younger patients are more amenable to intracavernous surgery, whereas firmer tumors in older patients may be best treated with radiosurgery or observation. For dissections involving the CS, the use of neuronavigation is useful as is the intraoperative Doppler probe. One of the major limitations of the endoscopic approach is the lack of proximal vascular control in the event of intraoperative hemorrhage. Therefore, it is important to define the course of the ICA with respect to the pathology and determine areas of safe entry into the CS. In addition, the availability of interventional radiology expertise is encouraged. Other important adjuncts to surgical success include the use of angled instrumentation, angled cameras, and intrathecal fluorescein injection.

The most frequent scenario in our experience is the invasion of a benign sellar tumor through the medial wall of the CS, which may be amenable to removal by use of the same transsphenoidal transsellar approach that is used for resection of the primary pituitary tumor. Tumors that arise primarily in the medial CS, or that extend into the CS from other anatomic regions such as the clivus, may be better accessed with the transthyroidal transsphenoidal parasellar approach. This approach avoids disrupting the normal pituitary gland within the sella, although there may be a greater risk of vascular injury because of the need for bone removal over the ICA. Tumors with substantial involvement of the lateral CS have traditionally been managed by craniotomy and a lateral-to-medial approach. These cases are associated with a greater risk of postoperative cranial neuropathy, and the decision to attempt endoscopic resection must be balanced against the potential morbidity. However, the endoscopic approach to lateral CS lesions is via the transmaxillary transpterygoid approach feasible and successful in well-selected individuals.

References