Surgical nuances for the endoscopic endonasal transpterygoid approach to lateral sphenoid sinus encephaloceles

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Lateral sphenoid encephaloceles of the Sternberg canal are rare entities and usually present with spontaneous CSF rhinorrhea. Traditionally, these were treated via transcranial approaches, which can be challenging given the deep location of these lesions. However, with advancements in endoscopic skull base surgery, including improved surgical exposures, angled endoscopes and instruments, and novel repair techniques, these encephaloceles can be resected and successfully repaired with purely endoscopic endonasal approaches. In this report, the authors review the endoscopic endonasal transpterygoid approach to the lateral recess of the sphenoid sinus for repair of temporal lobe encephaloceles, including an overview of the surgical anatomy from an endoscopic perspective, and describe the technical operative nuances and surgical pearls for these cases. The authors also present 4 new cases of lateral sphenoid recess encephaloceles that were successfully treated using this approach.

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The endoscopic endonasal transpterygoid approach has been used to gain exposure for a variety of skull base lesions. This approach was first used as an alternative to transfacial or sublabial approaches to access benign tumors in the PPF.20 However, with the rapid growth of endoscopic skull base surgery in the past decade through advances in imaging technology, instrumentation, and surgical techniques, and with increased cooperation between neurosurgeons and otolaryngologists, the number of lesions that are accessible using an endoscopic transpterygoid approach has increased considerably. Additionally, this procedure has now been reported to allow access to lesions in the infratemporal fossa, Meckel cave, petrous apex, and lateral sphenoid sinus.2,7,16–18,28,37 One of the more well-defined applications of this approach is its use to access the lateral recess of the sphenoid sinus.1,3,5,6,11,21,34 Accessing the lateral sphenoid sinus and its recess may be necessary in the management of sinonasal tumors (both benign and malignant) as well as in the repair of spontaneous or congenital meningoecephaloceles from this region.

Traditional microsurgical transsphenoidal approaches may not adequately expose these so-called far-lateral encephaloceles located in the lateral recess of the sphenoid sinus. This is due to the strictly midline nature of the exposure as well as the limited visibility and maneuverability restricted by an obstructing nasal speculum. Open frontotemporal transcranial approaches often require temporal lobe retraction, and transfacial approaches involve facial incisions and osteotomies to access these lateral sphenoid encephaloceles of the Sternberg canal. The primary advantage of the endoscopic endonasal transpterygoid approach is its ability to offer maximal exposure and panoramic visualization of encephaloceles in the far-lateral recesses of the sphenoid sinus without the risk of complications associated with brain retraction or facial osteotomies. The direct access given to these

Abbreviations used in this paper: PNSF = pedicled nasoseptal flap; PPF = pterygopalatine fossa; SPA = sphenopalatine artery.
latterly based encephaloceles through this approach also permits increased surgical maneuverability. Repair of CSF leaks arising from these encephaloceles can be safely and effectively performed with meticulous multilayered reconstruction, with or without a vascularized PNSF. In this paper, we review the endoscopic endonasal transpterygoid approach for treatment of lateral sphenoid sinus encephaloceles, and describe the operative nuances and surgical pearls associated with this technique. The endoscopic surgical anatomy is illustrated, along with 4 additional cases that are new to the literature.

Surgical Technique

Surgical Considerations

For endoscopic endonasal skull base procedures, we prefer to use a dual-surgeon approach, with a skull base neurosurgeon and an otolaryngologist specializing in rhinology, sinus, and endoscopic skull base surgery. We use a bimanual binostil technique, permitting 3 to 4 instruments to be used simultaneously throughout the procedure. Furthermore, by using a dual-surgeon approach, one surgeon can provide continuous dynamic manipulation of the endoscope and appropriate retraction when necessary, while the other can perform traditional 2-handed microsurgery in which endoscopic visualization of the surgical target is used. This strategy allows for maximal visualization throughout the entire procedure, improving depth of perception and permitting immediate reactionary changes in camera positioning that might be necessary throughout various components of the procedure.\(^2\) Using 2 surgeons, as opposed to a single "one-handed" surgeon holding the endoscope, also allows for more bimanual freedom of surgical maneuverability, which is of paramount importance in performing fine microdissection in deep critical targets of the skull base.

After the induction of general anesthesia, the patient is given 10 mg of dexamethasone, 50 mg of diphenhydramine, and 1.5 mg of cefuroxime. For the treatment of spontaneous CSF leaks and encephaloceles, we place a lumbar drain at the start of the case and infuse intrathecal fluorescein through the drain according to a protocol previously described by Tabaei and colleagues\(^3\) and Placantonakis et al.\(^4\) Ten milliliters of CSF is withdrawn from the lumbar drain and mixed with 25 mg of fluorescein (0.25 ml of injectable 10% solution; Akorn, Inc.), and then slowly injected back into the lumbar drain. This brilliant yellow indicator facilitates direct endoscopic visualization and localization of the site of origin as well as the direction of flow of the CSF leak. It is important to inspect for multiple encephaloceles during endoscopic exploration. This technique is also useful for intraoperative assessment of adequate repair, because the absence of any further visible fluorescein correlates strongly with a low risk of postoperative CSF leak.\(^5\)

Patient Positioning

Proper positioning of the patient is crucial to enabling this dual-surgeon approach. For combined endoscopic endonasal skull base cases, we typically secure the endotracheal tube on the patient’s left side, allowing both surgeons access to the patient from the right. The patient’s head is stabilized using a 3-point Mayfield frame. The head is slightly rotated toward the right and laterally bent to the left shoulder so that the patient’s face is pointing toward the surgeon standing on the right side. Image guidance using fine-cut CT scans is used for anatomical localization. We typically prepare the patient’s thigh and/or abdomen so that autologous fat or fascia lata can be harvested for graft reconstruction of the skull base defect, if needed.

The nose and nasal cavity are prepared with povidone-iodine, followed by placement of Afrin-soaked pledgets to decongest the nasal passages. The uncinate process, sphenopalatine foramen region, and the tail and anterosuperior attachment of the middle turbinate are infiltrated with 1% lidocaine with 1:100,000 of epinephrine solution for vasoconstriction.

Endoscopic Endonasal Approach to Sphenoid and Maxillary Sinuses

Using a 30° endoscope, the nostril ipsilateral to the encephalocele is explored. The middle turbinate is removed using a straight Thru Cut forceps. A posterior septectomy or septrotomy is then performed with endoscopic rongeurs and a microdebrider. These 2 steps enhance maximal maneuverability for the dual-surgeon, 4-instrument approach through binostil routes. Access through the contralateral nasal cavity allows a cross-court approach that provides a direct path for straight instruments to the lateral sphenoid recess. If a high-flow CSF leak and/or a large skull base defect is being repaired, we prefer to harvest a unilateral vascularized PNSF during the initial exposure of the sphenoid sinus for later reconstruction of the skull base defect. The operative details of harvesting the PNSF are described elsewhere.\(^6\) The PNSF is stored in the nasopharynx throughout the procedure until later use. It is important not to violate or traumatize the PNSF and its vascular pedicle during the operation, to maximize its potential in preventing postoperative CSF fistula formation.\(^7\)

The approach begins with resection of the uncinate process and identification of the natural ostium of the maxillary sinus. This is usually performed using a 30° rigid endoscope. The maxillary sinus ostium is subsequently widened posteriorly in the region of the posterior fontanel of the maxillary sinus until its posterior wall is reached. A total ethmoidectomy is then performed by sequentially resecting the ethmoid bulla, suprabullar cells, and the posterior ethmoid cells by transgressing the basal lamella (also called the third or ground lamella; this structure separates the anterior ethmoid cells from the posterior ethmoid cells) of the ethmoid sinus. The sphenoid sinus is then entered via an inferomedial transethmoidal approach. The sphenoidotomy should be widely enlarged to allow maximal exposure and permit optimal maneuverability within the sinus. If a PNSF has not yet been harvested at this point, care should be taken while enlarging the sphenoid sinus inferiorly to prevent injury to the vascular pedicle of the flap, which courses just inferior to the sphenoid sinus ostium. Although we do not routinely
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use a PNSF for small defects, if a large defect is expected, an attempt is made to preserve the vascular pedicle of the PNSF. In cases in which the vascular pedicle cannot be preserved and a large defect is noted after the resection portion of the case, the contralateral PNSF may be an option. If significant inferior pneumatization of the lateral sphenoid sinus recess into the pterygoid plates is noted, the inferior turbinate may be removed to allow maximal visualization of the posterior wall of the maxillary sinus and adequate inferolateral access to the recess (although this is rarely needed in our experience). Next, the mucosa of the posterior wall and roof of the maxillary sinus is elevated to permit access to the PPF through the postero-medial wall of the maxillary sinus.

Transpterygoid Approach to the Lateral Sphenoid Sinus

To obtain full visualization of the PPF and associated neurovascular structures, the orbital process of the palatine bone and the posteromedial wall of the maxillary sinus must be removed. The contents of the PPF include the internal maxillary artery, which gives rise to the SPA (Fig. 1), the descending palatine artery, the posterosuperior alveolar artery, the pterygopalatine ganglion, and the infraorbital nerve. The anterior compartment of the PPF contains the vascular structures and fat, whereas the posterior compartment contains the neuronal structures. The contents of the PPF must be retracted laterally to allow exposure of the lateral wall of the sphenoid sinus and further bone dissection. The sphenoid process of the palatine bone must be removed, followed by the medial pterygoid plate. This can be achieved using powered instrumentation (such as a high-speed drill) or Kerrison rongeurs. The vidian nerve may be identified and preserved by exposing it at the junction of the medial pterygoid plate and floor of the sphenoid sinus. This is best accomplished by limiting drilling to the inferior portion of the medial pterygoid plate. Although this nerve may be sacrificed, it can be used as a helpful tool in identifying the internal carotid artery in more complex cases when followed posteriorly. With successful drilling of the pterygoid process, the lateral recesses of the sphenoid sinus should be widely exposed, with sufficient room to access and repair the skull base defect. While dissecting through the medial aspect of the PPF, the SPA will be encountered as it exits the sphenopalatine foramen. The SPA provides vascular supply to the ipsilateral PNSF. Often, this artery cannot be preserved while dissecting the PPF, which will make an ipsilateral nasoseptal flap avascular.

Resection of Encephalocele and Skull Base Reconstruction

Once the lateral recess of the sphenoid sinus is exposed, the lateral sphenoid encephalocele is identified using angled endoscopes, with the aid of image guidance. Active CSF egress can be identified by intraoperative visualization of fluorescein. Smaller encephaloceles can be shrunk with bipolar cautery, whereas larger encephaloceles presenting with neural masses in the sphenoid sinus may need to be debulked with a suction-rotation microdebrider. In the majority of cases, the encephalocele consists of nonfunctional neural tissue, which can be removed without neurological consequences. This is more true in cases with very small dural and bony defects (narrow-necked encephaloceles) despite the size of the intranasal encephalocele. Once the encephalocele is minimized down to the level of the bony skull base defect, hemostasis is carefully obtained and the edges of the bony and dural defects are defined with an angled dissector or curette. It is important to denude the sphenoid sinus of all mucosa, especially around the bony skull base defect, to prevent intracranial entrapment of sinonasal mucosa, which can lead to late development of an intracranial mucocele. Removal of the sphenoid sinus mucosa also prevents mucosal secretions from separating the grafting material from the underlying bone (a phenomenon that can lead to repair failure). A small moist pledget is carefully pushed into the defect by using a dull probe (frontal sinus probe or maxillary sinus seeker) to define the edges clearly and to provide enough space for placement of an underlay graft.

The method for closure of lateral sphenoid sinus encephaloceles largely depends on the size of the defect being repaired. In general, this is accomplished with multilayered free tissue grafts for smaller defects or a multilayer method that includes a PNSF for larger defects with high-flow CSF leaks. In smaller defects (≤ 1 cm²), layers of Gelfoam (Pharmacia) or autologous fat buttressed by local rigid cartilaginous, bony, or synthetic grafts with an overlay of tissue sealant (Tisseel or DuraSeal) have been reported, and should be sufficient to close the defect and prevent postoperative CSF leaks. Alternatively, an au-
tologous fat graft can also be used to pack the sphenoid sinus to buttress the defect repair. Larger defects (> 1 cm²) with high-flow CSF leaks may require multilayered watertight closure with a PNSF, or with a free mucosal overlay graft.

At our institution, for small defects we prefer to use an initial layer of thin acellular dermal allograft (LifeCell Corp.) to plug the defect. The allograft is pushed into the defect by using a blunt angled probe, followed by gentle pressure exerted using a cottonoid pledget. At this juncture, no visible fluorescein-tinged CSF extravasation should be present. A second layer of thick implantable acellular dermal allograft is subsequently used to cover the initial graft. Gentamicin-soaked Gelfoam pledgets are then used to cover and buttress the grafts. For larger defects, we prefer to use an initial underlay graft using either autologous fascia lata or thick implantable acellular dermal allograft. This initial layer is covered with a monolayer of Surgicel (Ethicon, Inc.). A second layer of fascia lata or acellular dermal allograft is used, followed by placement of the previously harvested PNSF. Details of proper placement of grafting materials have been well established. Although in our earlier cases we frequently used dural sealants over the PNSF at this juncture, we have found no significant advantage to their use in a recent retrospective study, and have discontinued this practice.8 The grafts are subsequently covered with multiple layers of gentamicin-soaked Gelfoam pledgets and bolstered and buttressed with a bacitracin-covered expandable Merocel nasal tampon, which is inflated with gentamicin solution.

Postoperative Management

As with all skull base defect repairs, limiting activities that increase intracranial pressure is crucial to maintaining closure and preventing the formation of postoperative CSF fistulas. Patients are thus asked to avoid activities such as sneezing and straining, and are placed on stool softeners. In our practice, the patient is maintained on postoperative antibiotics (cephalosporin or β-lactamase–resistant penicillin) until the packing is removed approximately 10 days later in an outpatient visit. Last, the patient should be educated regarding the signs of postoperative CSF leak or infection, such as clear rhinorrhea, postnasal drip, fever, nuchal rigidity, and purulent nasal discharge, and should be closely observed. We typically remove the lumbar drain at the end of the surgery so that the patient is encouraged to mobilize earlier to avoid thromboembolic and pulmonary complications. The patients are usually discharged on postoperative Day 1 or 2. Postoperative follow-up consists of clinical examinations and direct nasal endoscopy to assess for CSF leak and to ensure successful repair and mucosalization of the graft; visits are scheduled at approximately 1, 3, 8, and 12 weeks, and then every 6 months after surgery.

Illustrative Cases

Case 1

This 52-year-old woman with a history of head trauma presented with recurrent right-sided CSF rhinorrhea and was admitted to another hospital for meningitis. On nasal endoscopy, a gray, right-sided sinonasal mass suggestive of an encephalocele was found. A CT scan of the paranasal sinuses showed a right-sided sinonasal mass extending to the frontal sinus as well as an encephalocele in the left lateral sphenoid recess (Fig. 2). The patient underwent endoscopic resection of the encephaloceles and reconstruction of the skull base defects. The encephalocele in the left lateral sphenoid recess was repaired using a layer of thin acellular dermal allograft to tuck the small defect, followed by a layer of thick implantable dural allograft. The allografts were covered with gentamicin-soaked Gelfoam pledgets, and buttressed with Merocel nasal packing covered with bacitracin. The patients’ postoperative course was unremarkable. She was asymptomatic and well healed at her 6-month follow-up and was lost to follow-up afterward.

Case 2

This 58-year-old woman presented with spontaneous CSF rhinorrhea from the left nostril. A CT and MRI session demonstrated a left lateral sphenoid encephalocele arising from the mesial temporal lobe and extravasating through a skull base defect (Fig. 3). An endoscopic transpterygoid approach was performed to expose the lateral recess of the left sphenoid sinus (Fig. 4). A large encephalocele was identified and debulked down to the skull base defect with a rotation-suction microdebrider. Using a 30° and 70° endoscope, the defect was repaired with a small piece of thick implantable acellular dermal allograft tucked as an inlay graft, followed by a vascularized PNSF. There was no evidence of active fluorescein extravasation at the end of the repair. Postoperatively, the patient was neurologically intact, with no further evidence of CSF leakage after 14 months of follow-up.
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Case 3

This 59-year-old woman presented with intermittent CSF rhinorrhea from the left nostril shortly after having undergone a cranietomy on the left side for removal of an intracranial mucocele at another hospital. A left-sided lateral sphenoid encephalocele extruding through a medial middle fossa defect was confirmed on a CT cisternogram, which showed extravasation of dye into the left sphenoid encephalocele (Fig. 5). Testing of the CSF also confirmed positivity for β₂-transferrin. The patient was referred to our center, where an endoscopic transpterygoid approach was performed. The encephalocele was identified with 30° and 70° endoscopes. The defect was repaired with acellular dermal allograft followed by an autologous fat graft in the sphenoid sinus. Postoperatively, the patient was neurologically intact, with no further evidence of CSF leakage after 12 months of follow-up.

Case 4

This 58-year-old, obese woman with a history of benign intracranial hypertension presented with clear, intermittent, right-sided CSF rhinorrhea that was positive for β₂-transferrin. She had a long history of chronic headaches and chronic sinusitis, with 3 previous endoscopic sinus surgeries. Interestingly, her headaches improved once the CSF leak began. The MRI studies demonstrated a lateral sphenoid encephalocele with opacification of the right sphenoid sinus. A partial empty sella was also identified, which was consistent with her history of benign intracranial hypertension. A CT cisternogram confirmed the pathway of the CSF leak (Fig. 6). Because of the underlying intracranial hypertension, we thought that direct repair without long-term CSF diversion would pose a high risk of postoperative CSF leakage. We therefore performed an initial ventriculoperitoneal shunt insertion followed by endoscopic repair of the CSF leak and skull base defect via an endonasal transpterygoid approach. A small defect was identified, with a herniation of neural

Fig. 3. Case 2. Axial (A) and coronal (B) CT scans demonstrating a left middle fossa skull base defect from an encephalocele in the left lateral sphenoid recess. Axial (C) and coronal (D) T2-weighted MRI studies demonstrating hyperintense opacification in the left sphenoid sinus.

Fig. 4. Case 2. Intraoperative views of the endoscopic transpterygoid approach. A: Extravasation of fluorescein-tinged CSF arising from the skull base defect in the lateral recess of the left sphenoid sinus. B: A thick acellular dermal allograft is placed as an inlay graft to plug the defect initially. C: Panoramic endoscopic view demonstrating the left maxillary sinus, left sphenoid sinus, and drilled pterygoid process. D: The PNSF is rotated over the skull base repair.

Fig. 5. Case 3. Coronal (A) and axial (B) CT scans demonstrating a left middle fossa skull base defect from an encephalocele in the left lateral sphenoid recess. The CT cisternogram (A) demonstrates extravasation of contrast into the encephalocele. Coronal (C) and axial (D) T2-weighted MRI studies demonstrating hyperintense opacification in the left sphenoid sinus.

Fig. 6. Case 4. Coronal CT cisternogram (left) and axial T2-weighted MRI study (right) demonstrating a right middle fossa skull base defect (green arrow) from an encephalocele in the right lateral sphenoid recess (asterisk). LPP = lateral pterygoid plate; MPP = medial pterygoid plate.
tissue extravasating CSF. The encephalocele was amputated with a pituitary rongeur and the defect was repaired with a collagen-based dural allograft inlay, followed by Surgicel to plug the dural defect. A free mucosal graft was used as an overlay to cover the skull base defect, and was further buttressed with an autologous fat graft placed in the sphenoid sinus. Postoperatively, the patient was neurologically intact, with no further evidence of CSF leakage after 42 months of follow-up.

Discussion

Encephaloceles of the lateral sphenoid sinus are relatively rare. Large encephaloceles are commonly diagnosed in utero or at birth as the product of a large neural tube defect in embryogenesis. However, smaller encephaloceles may go unnoticed for years or spontaneously occur as a result of trauma, iatrogenic injury, or skull base erosion from inflammatory and neoplastic processes. These disorders may also occur spontaneously as the result of increased intracranial pressure forcing neural tissue through a congenitally weakened portion of the sphenoid bone. Congenital defects causing a persistent craniopharyngeal tract in the lateral sphenoid sinus are exceedingly rare, but tend to be the result of incomplete fusion of the embryonic precursors to the sphenoid bone. This bone is formed from the fusion of 5 cartilaginous plates that undergo independent endochondral ossification during embryogenesis before fusing.\(^{31}\) Most commonly, the presphenoid and basisphenoid fail to fuse with the greater wings of the sphenoid bone, which leads to a persistent lateral craniopharyngeal canal known as the Sternberg canal,\(^4\) after the physician who first described it in 1888.\(^{32,33}\) Patients with encephaloceles of the lateral sphenoid sinus may present with headache, imbalance or dizziness, unilateral clear rhinorrhea, diplopia, or meningitis.\(^5\) Additionally, patients with this defect may be completely asymptomatic, and this lesion might go undiagnosed until it appears as an incidental finding on imaging studies. Regardless, patients with lateral sphenoid sinus encephaloceles should be evaluated for surgical repair to relieve symptoms and reduce the risk for later complications such as meningitis.

Due to their anatomical location deep within the skull base, encephaloceles of the lateral sphenoid sinuses can be challenging to reach with traditional microsurgical transnasal and transfacial approaches. Traditionally, these lesions were accessed by more standard approaches, including the classic midline transseptal transsphenoidal approach, LeFort I transmaxillary approach, and the frontotemporal–anterior middle cranial fossa approach.\(^{15,22}\) However, these approaches may result in more difficulty in accessing encephaloceles in patients who have far-lateral pneumatization of the sphenoid sinus, an anatomical variant seen in approximately 22%–40% of individuals.\(^{5,29,38}\) Since this variant also carries an increased risk for encephalocele formation,\(^{26}\) the ability to access this region is a cornerstone of endoscopic management of sphenoid encephaloceles. Alternatively, an extradural frontotemporal approach (with or without intradural exploration) with gentle brain retraction can be readily performed for exposure of lateral sphenoid encephaloceles. The associated temporal encephalocele can be amputated and the dehiscent dura mater and skull base defect can be repaired with autologous tissue grafts.\(^{22}\)

Initial attempts at repairing skull base defects in the lateral sphenoid sinus via a midline microsurgical transsphenoidal approach were associated with a high rate of failure because of poor visualization of these defects.\(^{22}\) In most cases, the laterally based defect of the Sternberg canal is situated beyond the line of sight of the speculum-based exposure. Wider exposures can be obtained with traditional extracranial transfacial approaches, such as the LeFort I osteotomy. However, these may be associated with postoperative malocclusion or traction neurepaxia of the infraorbital nerves as well as injury to the hard palate and upper alveolar region affecting the neurovascular supply to the teeth.\(^{21}\) The endoscopic endonasal transpterygoid approach offers several advantages, including avoidance of a craniotomy and brain retraction, excellent panoramic visualization of the lateral sphenoid recess, improved illumination, and increased surgical freedom for maneuverability of surgical instruments by eliminating the traditional nasal speculum. Also, the use of angled endoscopes and instruments is helpful in visualizing and accessing the far-lateral sphenoid sinus. Meticulous multilayered reconstruction is critical to successful repair of CSF leaks, and the aid of intraoperative fluorescein is vital to ensure that the repair is adequate. The advent of the vascularized PNSF is very effective in repairing larger defects with high-flow CSF leaks due to the robustness and vascularity of the tissue. In our experience with the closure of skull base defects with a PNSF, we have found that the majority of these encephaloceles can be repaired successfully without postoperative CSF diversion, unless of course there is a history of benign intracranial hypertension (as in Case 4).\(^{10}\)

Conclusions

The endoscopic endonasal transpterygoid approach enables excellent visualization and surgical access to encephaloceles arising from the lateral recess of the sphenoid sinus. These lesions can be safely resected and effectively repaired with a variety of multilayered reconstruction techniques, including the use of a vascularized PNSF if necessary. Although other transcranial and transfacial approaches have been successfully performed in the past, the endoscopic endonasal transpterygoid approach offers direct access to these lesions with no brain retraction, decreased operative risks, and improved cosmetic outcome.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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