

Treatment Strategies for Lateral Sphenoid Sinus Recess Cerebrospinal Fluid Leaks

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Objective: To highlight concepts critical to achieving successful repair and avoiding intracranial complications in the treatment of cerebrospinal fluid (CSF) leaks from the lateral recess of the sphenoid sinus (LRS).

Design: Outcomes study.

Setting: Tertiary referral university hospital.

Patients: Eleven patients with LRS CSF leaks from June 2008 to June 2010.

Interventions: Endoscopic transpterygoid approach and multilayer repair of skull base defect in the LRS.

Main Outcome Measures: Recurrence, graft techniques, postoperative intracranial pressure (ICP), and use of ventriculoperitoneal (VP) shunt.

Results: Thirteen CSF leaks originating in the LRS were surgically repaired in 11 patients; 2 patients required bilateral leak repair. The endoscopic transpterygoid approach was used in 12 of 13 repairs. Eight patients had failed attempts at repair prior to presentation (4 endo-

scopic sphenoidotomies and 4 middle cranial fossa [MCF] approaches). One patient presented with a temporal lobe abscess following hydroxyapatite “obliteration” to seal off the LRS. This required a combined MCF/transpterygoid approach to drain the abscess, remove the encephalocele and hydroxyapatite, and seal the skull base defect. In 2 cases, the LRS was left patent owing to concerns of inadequate mucosal extirpation. The median duration of follow-up was 10.8 months (range, 2-29 months). One patient experienced a failure (2 months after repair), which was successfully sealed on the second attempt. Postoperatively, 5 patients required VP shunts, and 5 were maintained on acetazolamide for elevated ICP (average, 26.7 cm H₂O in 8 patients; presumed elevated in 2 patients).

Conclusions: The current study demonstrated a 92% success rate using the endoscopic transpterygoid approach for LRS skull base defects providing support for routine use in the treatment algorithm. Poor outcomes were observed with previous surgical attempts to obstruct the LRS without repairing the skull base defect.

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TREATMENT STRATEGIES FOR repairing cerebrospinal fluid (CSF) leaks have changed dramatically over the past 20 years. Where open craniotomies for CSF leaks and associated encephaloceles were once standard procedures for skull base defects, transnasal endoscopic techniques have become the gold standard for CSF leak repair with success rates higher than 90% in most series.¹ Cerebrospinal fluid leaks and encephaloceles are typically categorized into 4 general classifications based on etiology: congenital, neoplastic, traumatic (including iatrogenic), or idiopathic etiologies.²⁻⁵ The idiopathic, also referred to as “spontaneous” etiology, has in

large part been attributable to the presence of increased intracranial pressure (ICP) and is often considered a variant of benign (also termed idiopathic) intracranial hypertension.² The presence of a skull base defect can increase the risk of pneumocephalus, meningitis, and brain abscess.⁶ With the exception of some CSF leaks resulting from blunt trauma, surgical repair is typically required, and the exposure of a defect is crucial to the success of the repair, especially in the frequent context of increased ICP.^{1,7} The location of the skull base defect dictates the endoscopic approach and techniques necessary for surgical treatment. When present in the sphenoid sinus near the midline, standard transseptal or transnasal endoscopic tech-

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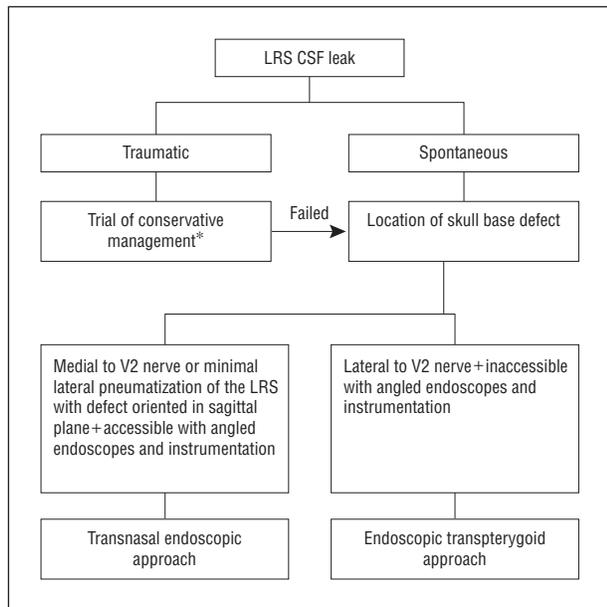


Figure 1. Algorithm for the approach to lateral recess sphenoid (LRS) cerebrospinal fluid (CSF) leaks. *Bed rest, stool softeners, and avoidance of strenuous activity for a period of 5 days before and after lumbar drain placement.

niques are usually adequate for closure.⁸ However, when there is a widely pneumatized sphenoid sinus extending into the lateral recess of the sphenoid sinus (LRS), these approaches are often insufficient for satisfactory repair. **Figure 1** demonstrates our treatment algorithm for repairing LRS CSF leaks. Overall, the LRS is a rare location to encounter a CSF leak, but our prior studies have revealed that this location is one of the most common areas (35%) for CSF leaks of a spontaneous etiology (elevated ICP).²

Because of the lateral location of the LRS behind the pterygopalatine fossa, the proximity of critical structures like the optic nerve and carotid artery, and the difficulty with a transnasal endoscopic approach to this area, some authors recommend obliteration of the sphenoid sinus without directly repairing the skull base defect.⁶ However, the endoscopic transpterygoid (TPTG) approach to the LRS allows direct exposure of the defect through total or partial removal of the pterygoid process (**Figure 2**).^{9,10} Herein, we highlight appropriate treatment strategies through a variety of patient presentations and focus on concepts crucial to the successful repair of skull base defects in this region.

METHODS

University of Alabama at Birmingham institutional review board approval was obtained prior to the initiation of this study. Prospective evaluation of patients who underwent surgical repair of LRS CSF leaks by the senior authors (K.O.R. and B.A.W.) from June 2008 to June 2010 was performed. Patient demographic variables and body mass index (BMI), calculated as weight in kilograms divided by height in meters squared, were reviewed. Other clinical parameters included presenting symptoms, associated intracranial sequelae, history of previously attempted repair (approach, technique, and complication), diagnostic radiography, surgical approaches, location of skull base

defect(s), disease process,⁹ synchronous skull base defects, graft type(s), and lumbar drains. Postoperative variables included ICP, use of acetazolamide or ventriculoperitoneal (VP) shunt for pressure reduction, follow-up duration, associated complications and/or recurrence, and LRS patency.

SURGICAL TECHNIQUE

The surgical technique (**Figure 2**) used by the senior author (B.A.W.) in nearly all patients is adapted from the approach first described by Bolger.¹⁰ Variations in the method of repair (typically dependent on anatomy and the disease process involved) are described in the following subsection. As part of our routine surgical treatment of patients with spontaneous CSF leaks, lumbar drains were placed by our neurosurgery team. Placement of drains in this subset of patients provides a means to (1) measure ICP, (2) inject fluorescein for defect localization, and (3) withdraw 5 to 10 mL of CSF during the ablation of the encephaloceles to assist with retraction and facilitate placement of epidural grafts.

An injection of 0.1 cm³ of 10% fluorescein diluted in 10 cm³ of the patient's own CSF was injected over 10 minutes as previously described.^{2,3,7,8,11} This is clamped and secured to the skin prior to the patient returning to the supine position. Computer-assisted stereotactic surgical navigation (InstaTrak, GE Healthcare; or Fusion, Medtronic) was used in all but 1 case in the present study.

A standard functional endoscopic sinus surgery is performed with a wide maxillary antrostomy to the posterior maxillary wall, complete ethmoidectomy, and sphenoidotomy. An angled 45° or 70° endoscope is used to initially visualize the lateral recess through the sphenoidotomy and confirm the presence of a CSF leak. Attention is then directed to the posterior wall of the maxillary sinus using 0° or 30° endoscopes. Following elevation of mucosa from the posterior maxillary wall, identification and dissection of the sphenopalatine neurovascular bundle is performed from a medial to lateral direction. The pterygopalatine fossa is exposed with removal of the posterior maxillary wall using 2-mm Kerrison punches and a 15° diamond burr. Adipose tissue is meticulously removed, and blunt dissection defines the internal maxillary artery for ligation and allows for preservation of the vidian nerve, infraorbital nerve, and sphenopalatine ganglia. The posterior wall of the pterygopalatine fossa is encountered, and the face of the pneumatized pterygoid process is removed superomedially to the pterygoid muscle attachments using a drill or Kerrison rongeurs. The goal on completion of the approach is not only total exposure of the encephalocele and associated skull base defect, but also complete mucosal extirpation from the LRS. Surgeon confidence in the ability to remove all the mucosa dictates obliteration vs maintaining sinus patency.

When the encephalocele is exposed, the tumor is ablated to the level of the skull base defect using either radiofrequency coblation¹²⁻¹⁴ (Coblator; ArthroCare ENT) or trans-sphenoidal bipolar cautery.

RECONSTRUCTION

The skull base defect following ablation of the encephalocele dictates our reconstructive technique (**Figure 3**). Because 12 of 13 of the CSF leaks in our cases were spontaneous, multilayered closure with septal bone and tissue inlay grafts were used in nearly all of these defects. Inlay tissue grafts used in this series were either Alloderm (LifeCell), Duragen (Integra), or Surgisis (Cook Medical).^{1-4,7,8,11,15,16} This was followed by placement of an overlay tissue graft with or without a free fat graft with an additional layer of a pedicled septal flap in certain cases for definitive closure of the recess.

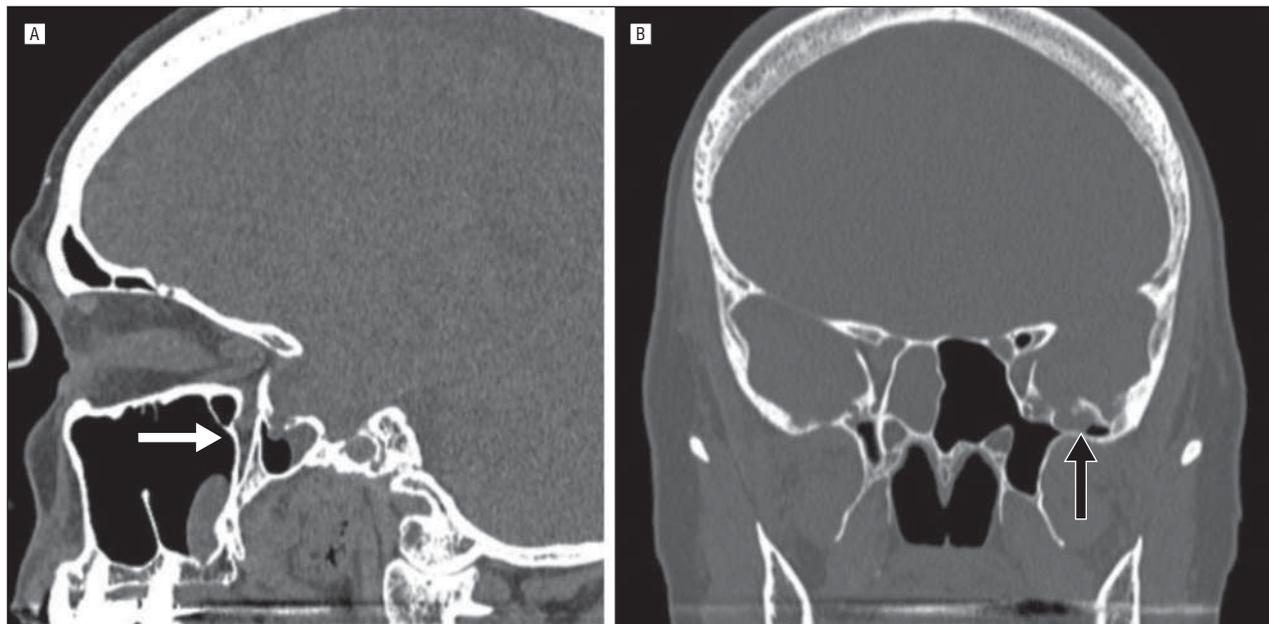


Figure 2. Sagittal computed tomographic (CT) scan demonstrating the direct access attained with a transpterygoid approach. A, The approach to the lateral recess (white arrow) of the sphenoid (white arrow) through the posterior wall of the maxillary sinus. B, The coronal CT scan demonstrates how this skull base defect is inaccessible using the transtethmoidal endoscopic technique owing to the narrow isthmus to the LRS and the far lateral and inferior location of the defect (encephalocele) (black arrow).

RESULTS

Thirteen CSF leaks in 11 patients originating in the LRS were surgically repaired. Given the location of the defects and guided by our algorithm for the approach (Figure 1), the endoscopic TPTG procedure was used in 12 CSF leaks. The demographic variables and history are included in **Table 1**. The median age at presentation was 56 years (range, 43-65 years). Eight of the 11 patients were female. The median BMI was 35.6 (range, 28.0-46.6). The median duration of follow-up was 10.8 months (range, 2-29 months), with a 92% success rate on first attempt. The presenting symptom in all patients included a component of CSF rhinorrhea. Three patients noted a history of meningitis prior to presentation. Computed tomographic scans of the sinuses confirmed the diagnosis suspected by history and physical examination in all patients; magnetic resonance imaging (MRI) was also useful in operative planning and diagnostic confirmation in 8 patients. Seven patients had empty sella syndrome on MRI.

All skull base defects were associated with an encephalocele and were approached using a TPTG technique as described. Only 3 patients had no prior surgical attempts to repair the CSF leak (patients 1, 5, and 11) (**Table 2**). Three patients (patients 6, 8, and 10) had undergone a total of 4 prior middle cranial fossa craniotomies that had failed to control the CSF leak. Three patients (2, 4, and 7) had received prior treatment with sphenoidotomy packing without success; these procedures did not achieve the endoscopic access to the lateral recess and directly address the defect. One such patient (patient 7) had her sphenoid sinus packed with hydroxyapatite; this led to a temporal lobe abscess, necessitating a middle cranial fossa and TPTG (above and below) approach for abscess drainage and defect repair. One patient was taken to

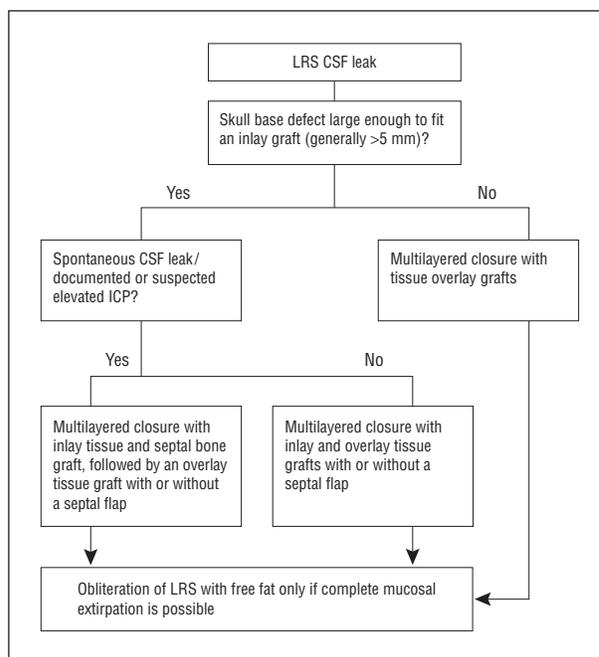


Figure 3. Algorithm for the reconstruction of lateral recess sphenoid (LRS) defects. CSF indicates cerebrospinal fluid; ICP, intracranial pressure.

surgery for repair of a possible ethmoid roof CSF leak prior to presentation at our institution, but the LRS defect had not been identified preoperatively on the MRI scans by the primary surgeon. Another patient had undergone 4 prior attempts at packing the LRS before referral for continued failure (**Figure 4** and **Figure 5**). A TPTG approach was attempted in patient 9 at an outside institution, but no attempt was made to remove the encephalocele, repair the defect, or remove the mucosa of the recess. Instead, an in-

Table 1. Preoperative Data

Patient No./ Sex/Age, y	BMI	Location	Etiology	Presenting Signs and Symptoms	Prior Surgery
1/F/65	30.0	L LRS	Spontaneous	CSF leak	None
2/F/56	28.7	R LRS	Spontaneous	CSF leak	Sphenoidotomy to pack sinus
3/F/46	31.9	R LRS, R cribriform	Spontaneous	CSF leak	ESS with graft placed over posterior ethmoid, CSF leak not identified
4/F/60	31.9	R LRS	Spontaneous	CSF leak	Sphenoidotomy to pack sinus ×4
5/M/58	43.3	Bilateral LRS	Spontaneous	CSF leak	None
6/F/47	32.6	L LRS	Spontaneous	CSF leak	MCF; transpterygoid (late failure)
7/F/48	42.3	L LRS	Spontaneous	Meningitis, temporal lobe abscess	Sphenoidotomy with hydroxyapatite
8/F/58	38.3	Bilateral LRS	GSW and spontaneous	CSF leak	MCF × 2 sphenoidotomy/partial transpterygoid
9/M/43	46.6	Bilateral LRS	Spontaneous	CSF leak	
10/M/62	38.6	Bilateral LRS	Spontaneous	CSF leak, meningitis	MCF 10 y prior; infected shunt
11/F/56	28.0	Bilateral LRS	Spontaneous	CSF leak	None

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CSF, cerebral spinal fluid; ESS, endoscopic sinus surgery; GSW, gunshot wound; L, left; LRS, lateral recess of the sphenoid sinus; MCF, middle cranial fossa; R, right.

Table 2. Operative Data

Patient	Defect 1	Operation	Defect 2	Operation	Acetazolamide	Shunt	Graft ^a	ESS	ICP, cm H ₂ O
1	L LRS	TPTG	None	ND	Yes	No	Duragen/bone	Yes	24
2	R LRS	TPTG	None	ND	Yes	No	Durarepair/bone	Yes	27
3	R LRS	TPTG	R ethmoid	Repair	No	Yes	Alloderm	Yes	ND
4	L LRS	TPTG	None	ND	Yes	No	Surgisis/bone	Yes	28
5	L LRS	TPTG	R LRS	TPTG/Sep Flap	No	Yes	Surgisis/bone/fat	Yes	30
6	L LRS	TPTG	None	ND	No	Yes	Surgisis/bone/fat	No	ND
7	L LRS	TPTG/MCF	None	ND	Yes	No	Surgisis	Yes	ND
8	L LRS	TPTG	R LRS	Not repaired	No	Yes	Surgisis/fat/septal flap	No	32
9	L LRS	TPTG	R LRS	Not repaired	Yes	No	Surgisis/bone/fat	Yes	35
10	L LRS	TPTG	R LRS	TPTG	No	Yes	Surgisis/bone/fat	No	32
11	R LRS	TPTG	L LRS	Not repaired	No	No	Surgisis/bone/fat	No	11

Abbreviations: Ecele, encephalocele; ESS, empty sella syndrome; ICP, intracranial pressure; L, left; LRS, lateral recess of the sphenoid sinus; MCF, middle cranial fossa; ND, not done; R, right; TPTG, transpterygoid.

^aAlloderm, LifeCell; Duragen, Integra; Surgisis, Cook Medical.

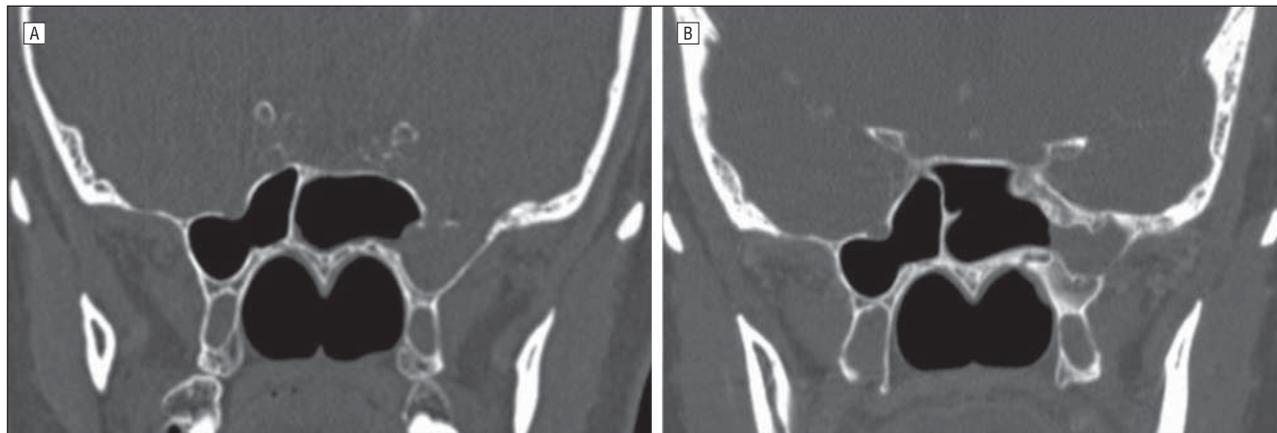


Figure 4. Patient 4. This patient had undergone 4 prior sphenoidotomies with “packing” without identification and repair of the associated encephalocele and skull base defect. The preoperative (A) and 6-month postoperative (B) coronal computed tomographic scans are depicted following a transpterygoid approach. The opacification seen postoperatively is a result of obliteration of the recess. Note the complete integration of the bone graft and thickened skull base (neo-osteogenesis) from removal of the mucosa.

ferior turbinate mucosal graft was placed over the TPTG area in an attempt to seal the LRS, which resulted in a recurrent CSF leak within 24 hours.

We had 1 patient in our series (patient 6) with a recurrent CSF leak. Interestingly, this was a late failure at 2 months postoperatively and was in the context of a func-

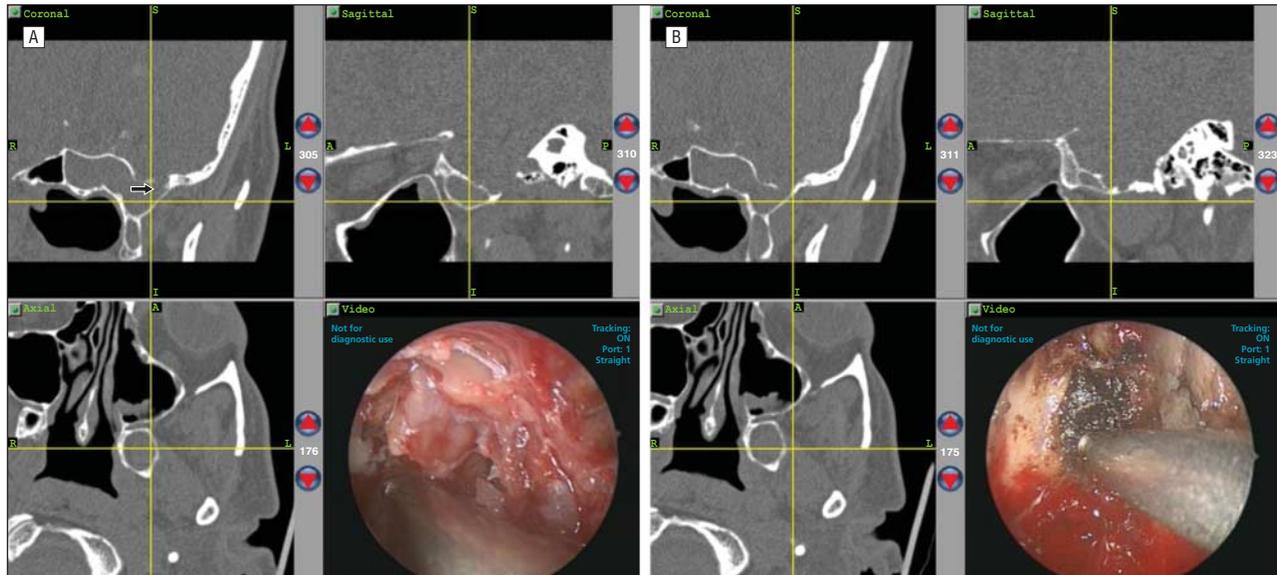


Figure 5. Combined triplanar computed tomographic (CT) imaging and endoscopic views of the lateral recess through a transpterygoid approach. A, The encephalocele is demonstrated with a suction probe placed through the back wall of the maxillary sinus. B, The left lateral recess skull base defect is defined (black arrow on coronal CT) following cauterization of the encephalocele up to the skull base defect.

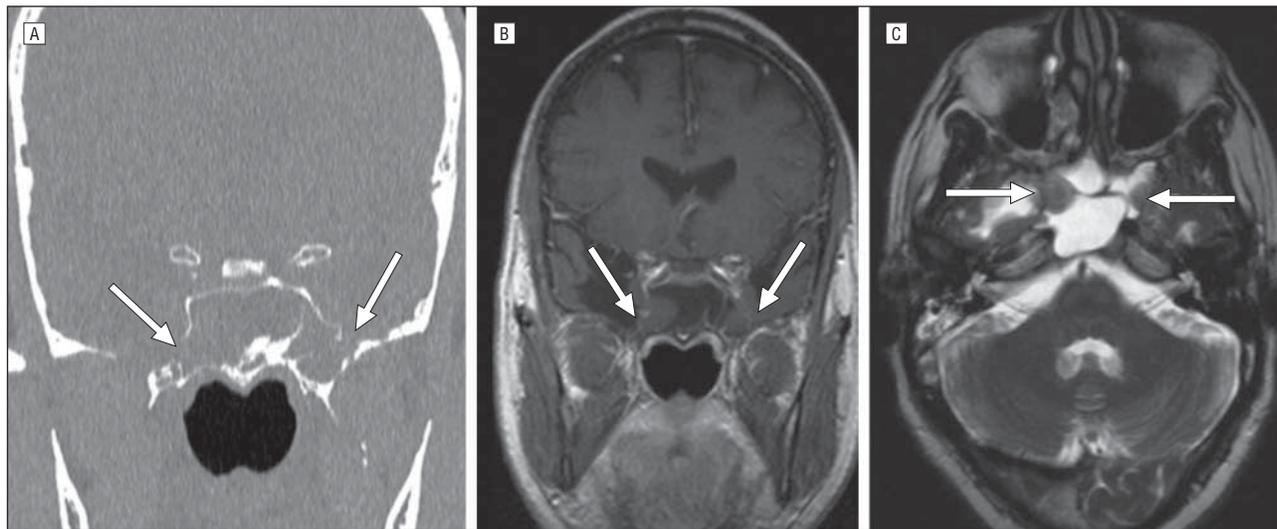


Figure 6. Patient 5. This patient presented with bilateral, spontaneous cerebrospinal fluid leaks from the lateral sphenoid recesses. A, Skull base defects (arrows) are present underlying the middle cranial fossa on computed tomographic scan. Note the sagittal orientation and minimal extension of the right lateral recess. Coronal T1-weighted (B) and axial T2-weighted (C) magnetic resonance imaging scans identify bilateral associated encephaloceles (arrows).

tional VP shunt. On secondary repair, the defect was repaired again using Surgisis dural underlay, septal bone underlay, Surgisis dural substitute overlay, obliteration of the free fat graft, and, finally, a contralateral pedicled septal flap to completely cover the obliterated lateral recess. Graft materials are shown in Table 2.

Six patients had a second, synchronous skull base defect. Patient 3 had a skull base defect in the ipsilateral ethmoid region, which was repaired concurrently. Patients 5, 8, 9, 10, and 11 had synchronous contralateral LRS defects; in patients 5 and 10 these were repaired concurrently (**Figure 6** and **Figure 7**). Patient 8 had a bullet from a self-inflicted gunshot wound lodged in the left LRS but was noted to have a contralateral synchronous spontaneous LRS defect. Because a contralateral pedicled septal flap was used to repair the large defect

caused by the bullet, performing a concurrent TPTG approach would have sacrificed the blood supply to the septal flap. When this patient had a VP shunt implanted to treat high ICP, her right “spontaneous” CSF leak was not clinically present, and she has elected to have careful clinical follow-up.

Eight patients had their ICPs measured postoperatively, and the average ICP was 26.7 cm H₂O (range, 11-35 cm H₂O). Three patients did not have lumbar pressure measurements recorded owing to (1) failure to obtain recordings prior to placement of a VP shunt for presumed idiopathic intracranial hypertension (subjective neurosurgical assessment was high ICP during ventriculostomy catheter placement) in patient 3, (2) replacement of a known malfunctioning VP shunt the day before surgery in patient 6, and (3) pressure readings following com-

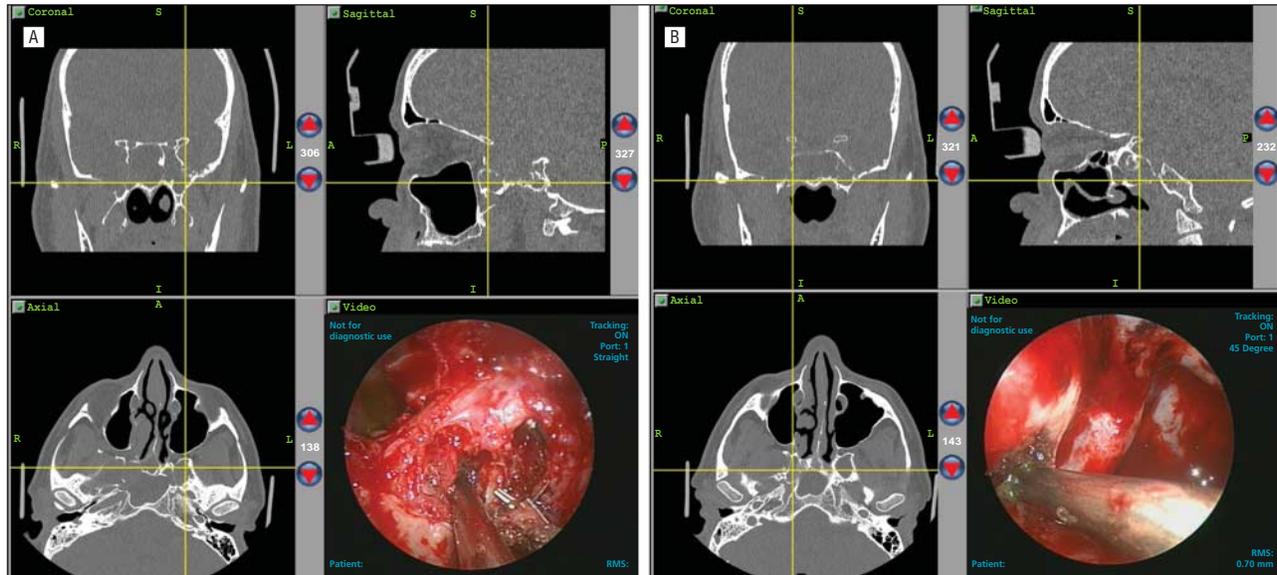


Figure 7. Intraoperative triplanar computed tomographic imaging with endoscopic views of the surgical approaches to the defects in Figure 6. A, Note the clips on the internal maxillary artery and the intact connections between the infraorbital nerve, sphenopalatine ganglion, and greater palatine nerve. B, The right defect was accessible with 70° endoscopy and instrumentation (encephalocele has been ablated) through a wide sphenoidotomy because the defect is oriented in the sagittal plane, the isthmus is wide, and there is no extensive lateral pneumatization.

combined endoscopic plus MCF approach for temporal lobe abscess that were felt to be an inaccurate representation in the setting of infection in patient 7. In all, acetazolamide therapy was initiated in 5 patients, whereas 5 patients required replacement for malfunctioning shunt (patients 6 and 10) or elective placement of a VP shunt for severely elevated ICP. Only 1 patient (patient 11) did not require postrepair intervention because she was found to have a postoperative ICP of 11 cm H₂O.

COMMENT

Overall, the LRS is a rare location to encounter a CSF leak, but our prior studies have demonstrated that the most common location for spontaneous sphenoid CSF leaks was the LRS (35%).^{2,7} Although some authors have felt that LRS CSF leaks are secondary to a patent lateral craniopharyngeal (Sternberg) canal,¹⁷ the predominant leak location is lateral to the sites of fusion of ossification centers and lateral to the second branch of the trigeminal nerve. The lateral craniopharyngeal canal is positioned medial to the superior orbital fissure, implying that an encephalocele originating through this theoretical canal must not only traverse the cavernous sinus but also penetrate 2 layers of dura mater before exiting the skull base. The current study and our prior work suggest that these leaks are indeed acquired rather than directly the result of a patent Sternberg canal.¹⁸ Nine of 11 patients in the present investigation had undergone prior unsuccessful attempts to address the disease process in the LRS. This allows an understanding and reiteration of certain key principles in the strategies for effectively treating this region.

CONTROL OF INCREASED ICP

All 11 patients in our study had a spontaneous CSF leak with associated encephaloceles, and 7 patients had ra-

diographic evidence of empty sella syndrome on MRI, a finding often seen in the context of idiopathic intracranial hypertension. These data are consistent with those in other published reports.¹⁶ The most important factor for a successful repair is decreasing ICP through any means necessary, including nutritional (significant weight loss), medical (acetazolamide), or surgical (VP shunt) means.^{2,7} Five of the patients in our series had elective placement of a VP shunt. Two of these patients had received prior VP shunts that had failed and were the foundation for persistence or recurrence of their CSF leak. Three patients had elevated ICP (> 30 cm H₂O) through lumbar pressure monitoring postoperatively, despite the use of acetazolamide, a carbonic anhydrase inhibitor that decreases the production of CSF. Four patients have been maintained on acetazolamide alone.

GRAFT TECHNIQUE AND PLACEMENT

While the graft material used varies among patients, the principle of underlay and overlay grafting is represented throughout our repairs in this series. As demonstrated in our reconstructive algorithm (Figure 3), our typical method of free graft repair involves using a dural substitute graft placed through the defect intracranially as an underlay graft. This is followed by a small bone graft placed in the defect. A graft (mucosa/fascia/cadaveric or xenograft) is held in place initially with Evicel tissue sealant (Ethicon) (Figure 8). If we feel that the mucosa can be completely extirpated from the LRS, obliteration is performed after the skull base is repaired with the 3-layer repair. A free fat graft is placed in the LRS, and an absorbable packing and a finger cot sponge pack are placed in the maxillary sinus against the obliterated wall for 1 to 2 weeks. It is our opinion that the LRS should be completely obliterated with fat only if all of the mucosa can be accessed and extirpated. If the mucosa cannot be confidently removed, it is

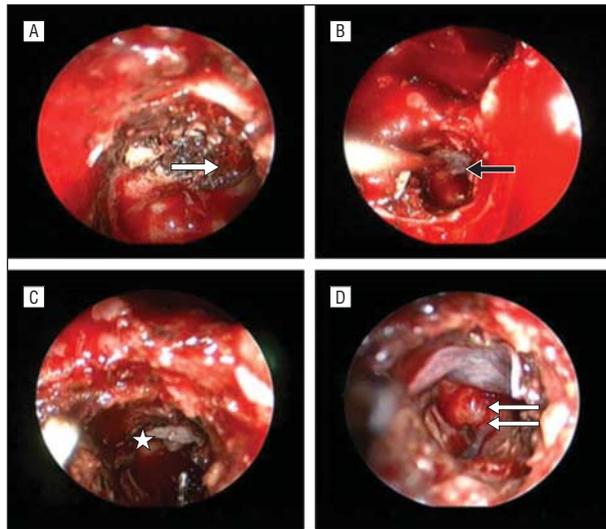


Figure 8. Intraoperative views of a multilayer skull base repair via a transpterygoid approach. A, The skull base defect (white arrow) is identified following ablation of an encephalocele. B, Surgisis (Cook Medical) dural graft (black arrow) is placed in an underlay fashion within the epidural space. C, An inlay bone graft (white star) is inserted beneath the Surgisis. D, Surgisis is then placed as an overlay graft (white arrows).

advisable to attempt patency of the LRS. This should decrease the potential for mucocele formation in the proximity of a skull base defect repair. As shown in our series, packing the sphenoid sinus (especially with hydroxyapatite) without identifying the actual skull base defect and without extirpating the sinus mucosa is not advisable.

We believe that our high success rate (92%) is due to the excellent exposure accomplished with the TPTG approach, the control of ICP, and our multilayered closure. We prefer to use bone to support the defect against the pulsations of CSF pressure. This may be an additional factor to prevent recurrence of a CSF leak from persistent elevation of the ICP. In our 1 failed repair, using our reconstructive algorithm (Figure 3), we added a contralateral septal flap to cover the obliterated LRS. We followed the patient for an additional 18 months with no recurrence.

BILATERAL LRS DEFECTS

Five patients in our cohort had bilateral skull base defects in the LRS. One patient (patient 10) underwent a bilateral TPTG approach. The other patient (patient 5) underwent a TPTG approach to 1 defect but had a contralateral defect that was accessible through a sphenoidotomy owing to a sagittal orientation. He received an ipsilateral septal flap repair for this defect (Figure 6 and Figure 7). Patient 9 did not have evidence of a CSF leak from a contralateral encephalocele. During a prior attempt to repair the actively leaking side via a TPTG approach at an outside institution, the infraorbital nerve had been damaged. The patient did not want the contralateral defect repaired at the time of his surgery. He elected to continue therapy with acetazolamide following definitive repair of the leaking side for treatment of his intracranial hypertension and is currently undergoing weight reduction management. Another patient (patient 8) had a CSF leak from

a self-inflicted gunshot wound with a bullet lodged in the left LRS. Owing to the enormity of the defect, a contralateral septal flap was placed following repair and fat obliteration. We also identified a contralateral defect preoperatively, consistent with arachnoid pits and elevated ICP. This was leaking intraoperatively, but a TPTG approach would have sacrificed the blood supply to the septal flap used to seal off the recess on the left. This patient's incidental defect and associated CSF leak were intended to be repaired in a staged fashion; however, to date, she has not experienced clinical leakage and prefers to have this managed through careful observational follow-up.

In conclusion, this series highlights several key principles regarding repair of skull base defects in the LRS. Extirpation of sphenoid sinus mucosa prior to obliteration should help prevent the formation of mucoceles and decrease the potential for temporal lobe abscesses or other intracranial complications. Transpterygoid exposure and identification of the entire skull base defect following encephalocele ablation seems to be an excellent approach for successful repair of LRS defects with low failure rate, as demonstrated in this case series.

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Author Contributions: All authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Alexander, Riley, and Woodworth.
Acquisition of data: Alexander, Riley, and Woodworth.
Analysis and interpretation of data: Alexander, Chaaban, Riley, and Woodworth.
Drafting of the manuscript: Alexander and Woodworth.
Critical revision of the manuscript for important intellectual content: Riley and Woodworth.
Statistical analysis: Alexander and Chaaban.
Obtained funding: Woodworth.
Administrative, technical, and material support: Chaaban and Woodworth.
Study supervision: Riley and Woodworth.

Financial Disclosure: Dr Woodworth is a consultant for ArthroCare ENT and Gyrus ENT.

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