Surgical Management of Sphenoid Sinus Lateral Recess Cerebrospinal Fluid Leaks: A Single Neurosurgical Center Analysis of Endoscopic Endonasal Minimal Transpterygoid Approach

Mustafa Onur Ulu[1], Seckin Aydin[2], Ahmet Kayhan[1], Baris Ozoner[3], Baris Kucukyuruk[1], Doga Ugurlar[4], Galip Zihni Sanus[1], Necmettin Tanriover[1]

■ OBJECTIVE: **To review the results of sphenoid sinus lateral recess (SSLR) cerebrospinal fluid (CSF) leaks treated with the endoscopic endonasal minimal transpterygoid approach (EEMTPA) and to discuss the surgical technique and outcomes.**

■ METHODS: **We performed a retrospective analysis of 13 cases who underwent SSLR CSF leak repair through the EEMTPA in our clinic between September 2008 and December 2017. Demographic and etiological features with reconstruction and surgical outcomes were examined. Mean follow-up time was 6.1 years.**

■ RESULTS: **In regard to etiology, the SSLR CSF leaks included 9 patients with spontaneous, 2 patients with traumatic, and 2 with iatrogenic causes. CSF leak was at the left lateral recess in 8 cases and at right lateral recess in 5 cases. Nine patients had empty sella syndrome, and 11 patients had meningoencephaloceles in addition to SSLR CSF leaks. All patients underwent surgery through the EEMTPA, and a multilayer closure with tissue overlay grafts were used for reconstruction. A pedicled nasoseptal flap and/or pedicled middle turbinate flap were applied to the area of the leak in all cases. One patient had a persistent CSF leak and another had recurrence, both of which required revision surgery. Our overall success rate was 100%.**

■ CONCLUSIONS: **EEMTPA is a safe and effective method that can be used to treat challenging pathologies at the SSLR, including CSF leaks accompanying meningoencephaloceles. Furthermore, the success rate of EEMTPA for SSLR CSF leaks can be increased by applying endoscopic skull base reconstruction techniques such as the pedicled nasoseptal flap and pedicled middle turbinate flap.**

INTRODUCTION

Endoscopic approaches make it possible to reach pathologies in the skull base that are located between frontal sinus and upper border of lower one third of clivus (dens) in the sagittal plane, or those between the 2 orbits superiorly and jugular foramens inferiorly in the paramedian plane. Also, endoscopic techniques are now regarded as the gold standard of treatment for cerebrospinal fluid (CSF) leak originating from this area.[1] It is possible to obtain a wider and clearer view of the transnasal/sphenoidal area with the endoscope. Case series with CSF leak treated with an endoscopic approach include various

Key words
- Cerebrospinal fluid leak
- Endoscope
- Sphenoid sinus lateral recess
- Transpterygoid approach

Abbreviations and Acronyms
CSF: Cerebrospinal fluid
CT: Computed tomography
EEMTPA: Endoscopic endonasal minimal transpterygoid approach
EETPA: Endoscopic endonasal transpterygoid approach
FR: Foramen rotundum
MEC: Meningoencephalocele
PMTF: Pedicled middle turbinate flap
PNSF: Pedicled nasoseptal flap
SSLR: Sphenoid sinus lateral recess
VC: Vidian canal

From the [1]Department of Neurosurgery, Istanbul University Cerrahpasa Medical Faculty, Istanbul; [2]Department of Neurosurgery, University of Health Sciences Okmeydani Training and Research Hospital, Istanbul; [3]Department of Neurosurgery, Erzincan University Medical Faculty, Erzincan; and [4]Department of Neurosurgery, University of Health Sciences Haseki Training and Research Hospital, Istanbul, Turkey

To whom correspondence should be addressed: Prof. Dr. Necmettin Tanriover, M.D. [E-mail: nctan27@yahoo.com]

Mustafa Onur Ulu and Seckin Aydin contributed equally to this work.

Citation: World Neurosurg. (2018) 118:e473-e482.
https://doi.org/10.1016/j.wneu.2018.06.219

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

groups of patients regarding the etiology (spontaneous, iatrogenic, traumatic) or localization (ventral midline skull base, sphenoid sinus lateral recess, clivus).[2,3] Among skull base CSF leaks, those that originate from the sphenoid sinus lateral recess (SSLR) are less frequent (7.7%), and endoscopic treatment of this area presents various challenges.[4]

In surgery of CSF leak originating from the lateral recess, it is possible to explore the defect by approaching this area via transsphenoidal route and with angled endoscopes. In contrast, the transnasal approach to SSLR may necessitate modifications of the standard transsphenoidal technique depending on patient's anatomical features. One major advantage of endoscopic endonasal transpterygoid approach (EETPA) to the SSLR is that it includes only the necessary requirement of bone resection, so that its ability to preserve sphenopalatine artery. Our aim in the present study was to examine the spontaneous, iatrogenic, or traumatic CSF leaks occurring from the SSLR on the basis of their clinical features and to present our surgical outcomes and complications through a modified EETPA.

MATERIALS AND METHODS

From September 2008 to December 2017, 43 endoscopic operations were performed in our clinic on 39 cases with CSF leak originating from various regions of the skull base due to various etiologies. Twenty-six of these patients underwent surgery for CSF fistula localized to the ventral midline skull base, and they were presented as a separate case series.[2] In the present study, we retrospectively reviewed 13 cases in our series who underwent treatment for CSF leak originating from SSLR, in terms of etiology, localization, accompanying defect, surgical approach, reconstruction techniques, surgical outcomes, and complications.

All of the cases presented with rhinorrhea, and as a diagnostic test, β-2 transferrin analysis was performed in the nasal discharge fluid of all cases. β-2 transferrin has 94%–100% sensitivity and 98%–100% specificity for demonstrating the presence of a CSF leak, and it is the gold standard test in diagnosis.[5] For those cases with positive β-2 transferrin results, magnetic resonance cisternography (Symphony; Siemens Medical Systems, Erlangen, Germany) was performed in 3 planes with T1-weighted, fat-saturated, and fluid-attenuated inversion recovery sequences 1 hour after intrathecal gadopentetate dimeglumine administration (or Magnevist; Schering, Berlin, Germany). Magnetic resonance cisternography was repeated at the third and fifth hour in case the CSF leak was not visualized. This technique can accurately show the localization of CSF leak or presence of meningoencephalocele (MEC) and allows a differential diagnosis of other pathologies that

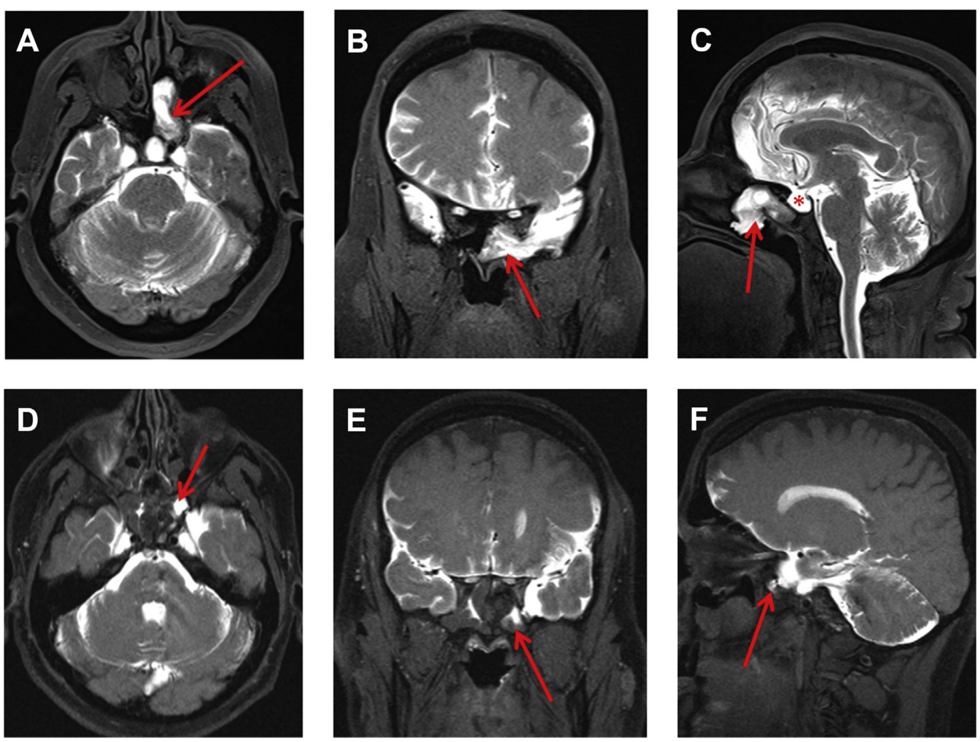

Figure 1. Case no. 4. (**A**) Axial T1-weighted (T1WI) magnetic resonance imaging (MRI). *Red arrow* shows the left sphenoid sinus lateral recess (SSLR) defect accompanying meningoencephalocele (MEC). (**B**) Coronal T1WI MRI. *Red arrow* shows the left SSLR defect and herniation of mesial temporal structures toward to the MEC. (**C**) Sagittal T1WI MRI. *Red arrow* shows left SSLR defect accompanying MEC, and the *red asterisk* indicates total empty sella. Case no. 11. (**D**) Axial T1WI magnetic resonance cisternography (MRC). *Red arrow* shows the left SSLR defect accompanying MEC and gadolinium contrast as a sign of cerebrospinal fluid (CSF) leak. (**E**) Coronal T1WI MRC. *Red arrow* shows the left SSLR defect and CSF leak. (**F**) Sagittal T1WI MRC. *Red arrow* shows the left SSLR defect and CSF leak.

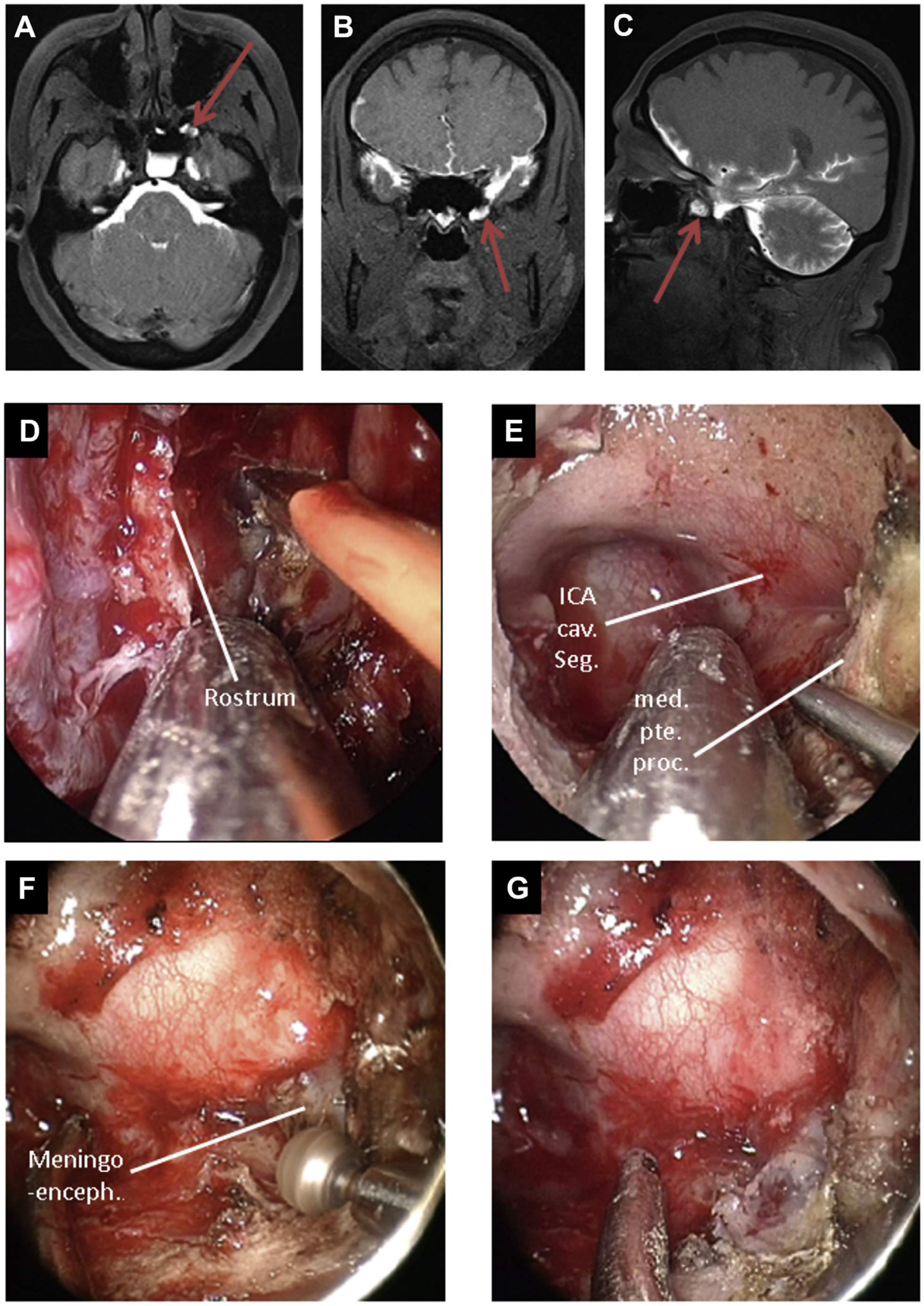

Figure 2. Case no. 13. (**A**) Axial T1-weighted (T1WI) Preoperative magnetic resonance cisternography (MRC). *Red arrow* shows the left sphenoid sinus lateral recess (SSLR) defect accompanying meningoencephalocele (MEC). (**B**) Coronal T1WI preoperative MRC. *Red arrow* shows the left SSLR defect and MEC. (**C**) Sagittal T1WI preoperative MRC. *Red arrow* shows the left SSLR defect and MEC. (**D**) Intraoperative photograph of binostril endoscopic endonasal approach. The posterior part of the nasal septum is removed, and the rostrum and left sphenoid ostium are seen. (**E**) Anterior wall of sphenoid sinus was is removed. Surgery is oriented to the cerebrospinal fluid leak side. Cavernous segment of the internal carotid artery and medial pterygoid process are seen. (**F**) Medial pterygoid process is drilled and MEC is localized. (**G**) Completion of bone drilling. (**H**) MEC was reduced in size by endoscopic bipolar cautery. (**I**) Better visualization of osteodural defect and MEC by a 30° angled endoscope. (**J**) Onlay repair (with obtained autologous graft) is applied over the defect area. (**K**) Pedicled nasoseptal flap is applied. (**L**) After reconstruction and fibrin glue application, a Foley catheter (balloon stent) is inserted to the anterior sphenoidal area posterior to the resected part of nasal septum. (**M**) Catheter is filled with 5 mL of saline to apply a light compression onto the reconstructed area. (continues)

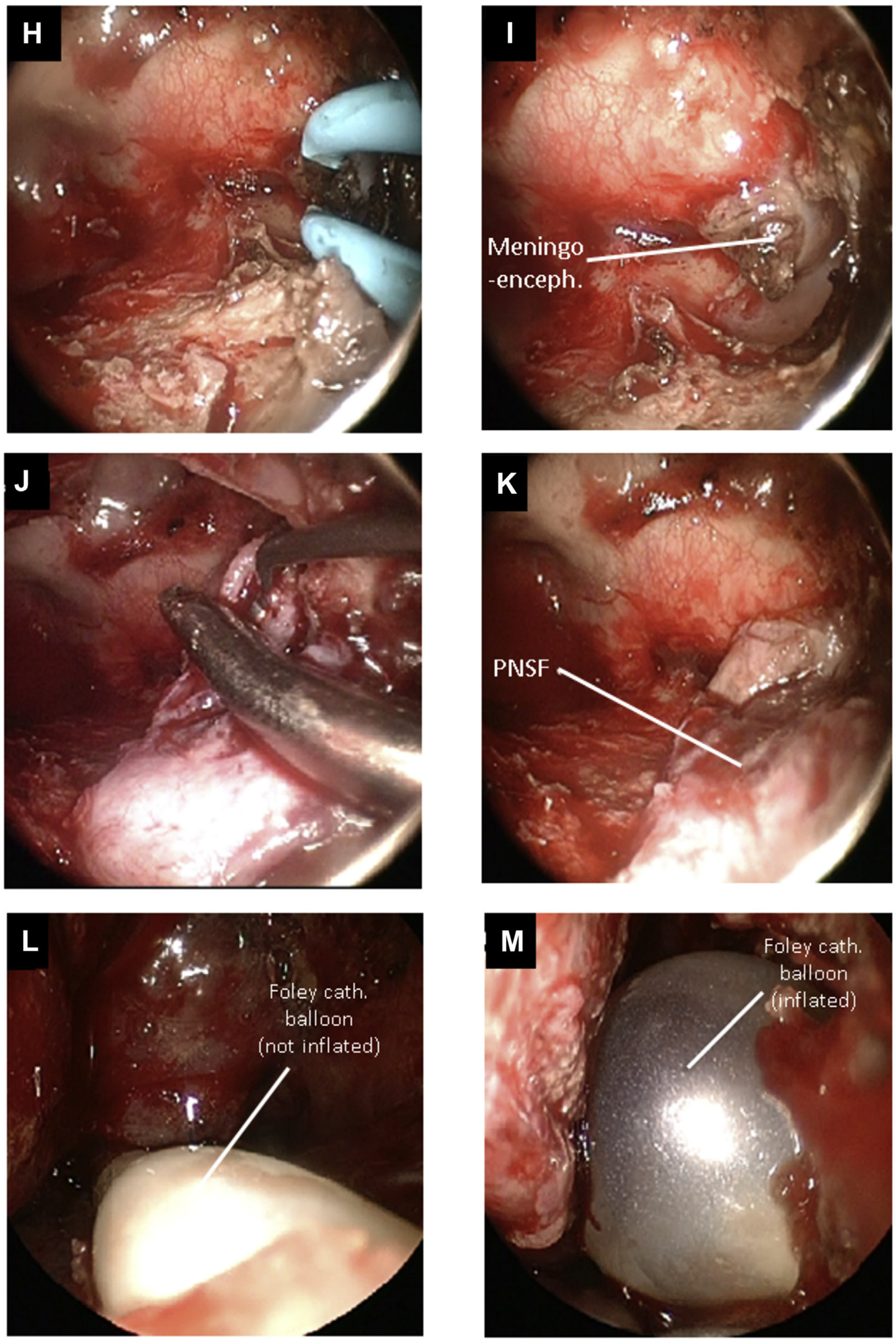

Figure 2. (continued)

Table 1. Demographic Data of Patients with Sphenoid Sinus Lateral Recess Cerebrospinal Fluid Leak

Case No.	Age, years	Sex	Etiology	Duration of Symptoms, weeks	Hospitalization, days	Empty Sella	Previous Surgery
1	67	F	Spontaneous	12	6	–	–
2	37	M	Spontaneous	3	20*	Partial +	TS (5 years ago)
3	14	M	Traumatic	4	12	–	TC (6 months ago, 4 months ago, 2 months ago: total 3 times)
4	58	F	Spontaneous	8	10	+	TC (17 years ago 2 times and 14 years ago: total 3 times)
5	32	F	Iatrogenic	4	8	–	–
6	57	F	Spontaneous	4	6	+	–
7	44	F	Spontaneous	20	6	+	–
8	49	F	Spontaneous	8	10	+	–
9	47	F	Traumatic	8	13	–	–
10	4	F	Iatrogenic	12	8	–	–
11	47	F	Spontaneous	12	5	+	–
12	39	M	Spontaneous	2	6	+	TC (6 years ago)
13	55	F	Spontaneous	24	5	Partial +	–

F, female; M, male; Partial +, partial empty sella syndrome; TC, transcranial; TS, transsphenoidal.
*Total days with second operation due to persistance of rhinorrhea.

can cause nasal discharge.[6] In addition, sella was radiologically visualized in the obtained images, and findings related to increased intracranial pressure, such as empty sella syndrome, were documented (Figure 1).

After confirmation of the CSF leak and localization of the leak site, a fine-cut (1-mm thickness) high-resolution computed tomography (CT) scan (MX 8000; Philips Medical Systems, Best, Netherland) through the skull base was performed to better define the surgical corridor and anatomy of the region and for preoperative planning. Informed consent was obtained from all patients.

Endoscopic Endonasal Minimal Transpterygoid Approach (EEMTPA)

Endoscopic endonasal transpterygoid surgery allows the approach to SSLR, provides a wider surgical field of view, and enables repair of rhinorrhea with high success rate.[1] One major advantage of endoscopic endonasal transpterygoid surgery includes the reduction of the amount of bone resection and elimination of vidian nerve transposition, in addition to its ability to preserve the sphenopalatine artery in necessary cases. In our series, we applied type B of the transpterygoid approach classification by Kasemsiri et al.[7] and preferred to rename this route as the EEMTPA.

Abdominal subcutaneous fat, fascia, and muscle were resected via a skin incision from the right lower abdominal quadrant to obtain an autologous graft before surgery. In all patients, the obtained grafts were sufficient. All patients were positioned with a skull pin head holder, and a neuronavigation system (Medtronic, Louisville, Kentucky, USA) was set up.

To reduce mucosal bleeding, cotton balls soaked in vasoconstrictor agents were placed. Then, the bi-nostril approach was initiated in a normohypotensive state. Endoscopic lenses with an outer diameter of 4 mm and angled at 0, 30, and 45° (Olympus Visera Pro CLV-S40Pro, Tokyo, Japan) were used in various stages of the operation. Initially, sphenoid ostiums were localized bilaterally through a bi-nostril approach. The middle turbinate at the side of the CSF leak was resected or prepared as a pedicled middle turbinate flap to be used in the reconstruction stage at the end of the operation in appropriate cases. Before the removal of posterior part of the nasal septum, the mucosa at the side of the lesion was separated from the septum cartilage and bone via submucosal dissection and resected to obtain a large nasoseptal flap.[8] Keeping the flap pedicle at the side of the sphenopalatine foramen and preserving the sphenopalatine artery, the flap was tipped over to the choana at the side it was obtained to be used at the end of the operation. The posterior part of nasal septum was resected to allow free motion of the endoscopic tools, and thus the 2 nasal cavities were united to form a single cavity. The superior turbinate at the side of the lesion was resected as required. The sphenoid sinus anterior wall and anterior aspect of pterygoid bone floor were drilled as lateral as the anterior orifice of the vidian canal (VC; approximately 1.5 cm lateral to the midline) with a high-speed diamond drill (Midas Rex; Medtronic, Humacao, Puerto Rico, USA). At this stage, adequate surgical space was gained to expose the MEC and osteodural defect localized in SSLR. The defect localization was confirmed with neuronavigation at this stage.

A 30° or 45° angled endoscope was used as required, and if present, the MEC was reduced in size by endoscopic bipolar cautery. Reconstruction was planned on the basis of the size of bone defect. Since the diameter of the defect was below 10 mm in all of our cases, we applied an onlay repair over the defect area. Obtained autologous graft (abdominal fascia) was laid and then pedicled nasoseptal flap (PNSF) or pedicled middle turbinate flap

Table 2. Surgical Data of Patients with Sphenoid Sinus Lateral Recess Cerebrospinal Fluid Leak

Case No.	Side	Size, mm	MEC	Reconstruction	Reoperation	Follow-up, years
1	L	3	+	PNSF	–	9
2	L	3	+	PNSF/PMTF	+	8
3	R	9	+	PNSF	–	8
4	L	9	+	PNSF	–	7
5	R	4	+	PNSF	–	7
6	L	6	+	PMTF	–	7
7	L	4	–	PNSF	–	6
8	R	5	+	PNSF/PMTF	+	6
9	L	3	–	PNSF	–	5
10	R	6	+	PNSF,	–	5
11	L	4	+	PNSF, PMTF	–	5
12	R	4	+	PNSF	–	4
13	L	5	+	PNSF	–	3

MEC, meningoencephalocele; L, left; PNSF, pedinculed nasoseptal flap, PMTF, pedinculed middle turbinate flap; R, right.

(PMTF) was placed on the reconstruction area, with attention paid to not compromise its blood supply. During the reconstruction phase, PNSF and PMTF were used in 12 and 4 patients, respectively. In 1 patient, both flaps were applied during the same session, whereas in 1 patient, only PMTF was used because mucosal flap was not appropriate. In addition, in 2 patients who showed recurrence after reconstruction with PNSF, PMTF was applied in the second operation.

PMTF or PNSF was placed on the defect with attention paid not to compromise its blood supply. Next, the obtained abdominal fascia was laid, and fibrin glue was applied for the second time. Lastly, a 12-F or 14-F Foley catheter (balloon stent) was inserted to the anterior sphenoidal area posterior to the resected part of nasal septum. Following its adjustment, the balloon was filled with 5 mL of saline in a controlled manner to apply a light compression onto the reconstructed area.

During the postoperative period, patients were immobilized during the first 24 hours. The catheter balloon was removed in a controlled manner after emptying the saline in the balloon on the second postoperative day to avoid its adhesion to the repaired area. Also, to avoid constipation, laxative treatment was administered routinely. The patient was asked to avoid blowing his or her nose. Removal of crusting was not applied to any of the patients (Figure 2).

RESULTS

Of all patients included in the study, there were 10 female and 3 male patients, and 2 patients were in the pediatric age group (4 and 14 years old). Age range was 4–67 years, with a mean age of 42.3 ± 17.6 years (mean value ± standard deviation). The interval between the onset of symptoms and presentation to hospital varied between 2 and 24 weeks, with a mean of 9.3 ± 6.6 weeks. Mean hospital stay length was 8.7 ± 4.3 days. Mean follow-up time was 5.1 ± 1.7 years. Table 1 presents an etiological and clinical analysis of patients. In all patients, the history consisted of the sign of (active) rhinorrhea, in addition to a history of recurring meningitis attacks in 3 patients. However, none of the patients had active meningitis at the time of operation.

Whereas CSF leak developed spontaneously in 9 patients, it was due to a history of trauma in 2 patients and to history of the previous operation within the adjacent sphenoidal area (iatrogenic) in the other 2 patients. Among the cases with an iatrogenic etiology, the first case (case 5) was operated on a year previously with the transcranial approach due to frontobasal meningioma and developed rhinorrhea within the last month. The case was found to have CSF leak and MEC localized to the right SSLR. The other case (case 10) had a history of operations on the right eye 4

Table 3. Review of the Endoscopic Approaches to SSLR CSF Leaks (Case Series with More Than 10 Patients)

Studies	No. Cases	SSLR	CSF +	Approach	Reconstruction	Success Rate % (1.op/2.op)
Tosun et al., 2003[21]	24	*	24	EEA	AF-SMPF-OGM/Obliteration-Overlay-underlay	92/100
Zoli et al., 2016[22]	23	23	19	EETPA	FL-NSF-OGM/Multilayer	100/NA
Janakiram et al., 2015[23]	21	16	21	EETPA	PNSF-OGM/Multilayer	100/NA
Castelnuovo et al., 2007[24]	15	15	15	ETS-TEPSA	AF-OGM/Obliteration-Multilayer	100/NA
Kirtane et al., 2012[25]	15	15	15	TEPSA	PNSF-AF-FL-OGM/Obliteration-Bath Plug Technique	100/NA
Tabaee et al., 2010[26]	13	13	11	TN-TPA-TEA	FL-OGM/Multilayer	85/100
Alexander et al., 2012[1]	11	11	11	EETPA	AF-PNSF-OGM/Obliteration-Multilayer	92/100
Our study, 2018	13	13	13	EETPA	AF-PNSF-PMTF-OGM/Obliteration-Onlay	85/100

CSF + means the number of cases with cerebrospinal fluid leak in these series.
SSLR, sphenoid sinus lateral recess; CSF, cerebrospinal fluid; EEA, endoscopic endonasal approach; AF, abdominal fat; SMPF, septal mucoperiostal flap; OGM, other grafting materials; EETPA, endoscopic endonasal transpterygoid approach; FL, fascia lata; NSF, nasoseptal flap; PNSF, pedinculed nasoseptal flap; ETS, endoscopic transsphenoidal approach; TEPSA, transethmoid-pterygoid-sphenoid approach; NA, not available; TN, transnasal; TPA, transpterygoid approach; TEA, transethmoidal approach; PMTF, pedinculed middle turbinate flap.
*Number of patients with SSLR CSF leaks were not specified.

times due to ocular disease from birth until 3 years of age. The case had persistent rhinorrhea for nearly 3 months, and a MEC and CSF leak was detected localized to right SSLR. In both patients, the fistula was repaired with EEMTPA as in other cases in the series.

Radiologically, CSF leak was detected in the left SSLR in 8 cases and right SSLR in 5 cases. Defect sizes ranged between 3 and 9 mm. Mean defect width was 5.1 ± 2.3 mm. Six patients had total empty sella syndrome, and 2 patients had partial empty sella syndrome; thus, 8 of the 9 patients (88.8%) with spontaneous CSF leak had signs consistent with empty sella syndrome. Excluding the patients in the pediatric age group, 10 of 11 patients were overweight (body mass index >25 kg/m^2), and 5 of these met the criteria for obesity (body mass index >30 kg/m^2). MEC was detected in 11 patients (Table 2).

All patients underwent surgery through an EEMTPA, and the CSF leak was treated successfully at the first attempt in 11 patients (84.6%). Two patients underwent reoperation. The first reoperated case (case 2) was a 37-year-old male patient who had been operated in an external center 5 years ago with the transsphenoidal approach due to spontaneous CSF leak. After his first operation with the endoscopic approach in our clinic, the patient was reoperated on the postoperative 12th day due to persistence of his rhinorrhea. The second reoperated case (case 8) was a 49-year-old female patient who had her first operation in our clinic due to spontaneous CSF leak. The patient was reoperated due to recurrent rhinorrhea after 7 months of follow-up. Neither of these 2 patients developed rhinorrhea during their follow-up after their second operations. Therefore, our overall success rate was 100%.

No intraoperative complication was observed in any of the patients. At the postoperative period, 1 patient developed an infection at abdominal graft donor area and completely healed without any further problems. Routine control examinations were performed for all patients at the postoperative third and sixth month and at the end of the first year, and radiologic evaluations were made with thin section skull base CT and cranial magnetic resonance imaging. The operation area was evaluated at least once with endonasal examination by an ear–nose–throat surgeon.

DISCUSSION

SSLR Terminology and Classifications

The widely adopted classification proposed by Hammer and Radberg[9] divided the sphenoid sinus into 3 types: conchal, presellar, and sellar based on the extent of pneumatization around the sella turcica. The vidian–rotundum line, the line connecting the medial edges of the anterior opening of the VC and the extracranial end of the foramen rotundum (FR), was defined as the demarcation between the sphenoid body and lateral parts of sphenoid bone, which include the greater wings and pterygoid process. The lateral recess is defined as the lateral air cells that extends laterally between the VC and the FR and beyond the sphenoid body into the greater wing and/or pterygoid process. Wang et al.[10] examined the SSLR and classified it into 3 types based on CT and magnetic resonance imaging: greater wing, pterygoid, or full lateral types. It is referred to as a greater wing type only if the pneumatization extends laterally between the FR and VC into the greater wing, as a pterygoid type only if the pneumatization extends laterally between the FR and VC and inferiorly into the pterygoid process, and finally, as a full lateral type if the sphenoid sinus extends laterally into both the greater wing and the pterygoid process. In this article, 200 lateral sinus walls examined on CT and the lateral type of extension was found in 92 (46%). Among this lateral recess extensions, the greater wing type was found in 11 (12%), pterygoid type in 10 (11%), and full lateral type in 71 (77%).

Vaezi et al.[11] also categorized the degree of pneumatization of the SSLR in the coronal plane into 3 distinct types. In type I (previdian type), the pneumatization extends from the midline to the medial edge of VC (25%). In type II (prerotundum type), it extends to the lateral edge of FR (39%); and in type III (postrotundum type), the pneumatization extends lateral to the FR (37%). In our series, all patients showed greater wing and full lateral types according to the classification of Wang et al. and type II and III pneumatization according to the classification of Vaezi et al.

SSLR CSF Leaks

CSF leak originating from the SSLR is a rare entity among all skull base CSF leaks. Despite this, spontaneous etiology of the leak is observed most frequently in this localization.[12] In our series, spontaneous CSF leak was encountered in the majority of the cases (9 of 13 patients). The predominance of middle age, obesity, and female sex that has been reported in the literature also was observed in the present case series.[13,14] We believe that all of these factors create a predisposition to CSF leak development at the SSLR. In addition, an empty sella appearance was detected in 62% of the cases (8 of 13 patients), which may be a sign consistent with increased intracranial pressure presenting with herniation of diaphragma sellae into sella turcica.[15]

Greater pneumatization of the sphenoid sinus and the thin-lamellar structure of the bone located at the skull base are thought to play role in development of bone defect in this area as a result of chronic effects.[16] In addition, there are several studies related to the lateral craniopharyngeal canal (Sternberg canal), which is a controversial subject in the literature.[17,18] This condition is reported to be a congenital pathology, arising as a result of the fusion defect between the greater wing and body of the sphenoid bone, arguably medial to the imaginary line drawn between FR and VC. The Sternberg canal (lateral craniopharyngeal canal) is known to be located medial to this imaginary line; in contrast, all MECs and CSF leaks within the lateral recess in our series were located lateral to this line. As stated by Illing et al.,[19] this suggests that the skull base defect is rather an acquired pathology. Another radiologic study that examined 1000 cases with CT reported that only 1 case showed no association with SSLR, in which there were signs consistent with Sternberg canal.[20]

Surgical Techniques and Outcomes

In the review of literature in English language, we encountered 7 series that related to endoscopic treatment of SSLR CSF leak including more than 10 patients. In their series, Tosun et al.[21] reported endoscopic treatment of 24 cases with sphenoid sinus CSF leak. However, they did not state the number of cases with CSF leak originating from the SSLR, nor did they give any information on the presence of MEC. They mostly used the obliteration technique with transnasal approach, but they also stated that septal mucoperiosteal flap was used in 2 cases. They reported a success rate of 92% after the first operations. In their series including 23 cases, Zoli et al.[22] applied EETPS. However, CSF leak occurred in only 19 cases as a presenting symptom. They used PNSF in all of their cases, and they reported a success rate of 100% in their series. For reconstruction, they applied multilayer fashion, and as a complication, only 1 case developed epileptic seizure. All of their cases had either meningocele (12 cases) or MEC (11 cases). Janakiram et al.[23] applied EETPS in their lateral recess CSF leak series including 16 cases, and reconstruction along with PNSF was performed in all cases. Their success rate was 100%, whereas 1 case developed fatal meningitis as a complication. Castelnuovo et al.[24] reported lateral recess CSF leak repair with the transethmoid-pterygoid approach in 15 cases with 100% success rate. They applied PNSF to 7 of their cases, and they did not observe postoperative complication in any of their cases.

Kirtane et al.[25] reported 15 cases of SSLR CSF leak that operated with a kind of trans-ethmoid-pterygoid-sphenoid approach, and their success rate was 100%. They described MEC in 3 cases, and they applied PNSF in 4 cases who had multiple small defects on the sphenoid wall. Tabaee et al.[26] reported a success rate of 85% after first endoscopic intervention to repair CSF leak in their series including 13 cases. Only 1 case required revision, and another case with persistent rhinorrhea healed without requiring a second intervention. MEC was detected in all cases, and postoperatively, 1 case developed meningitis and another developed facial paralysis as complications.

Alexander et al.[1] used a multilayer reconstruction technique with the transpterygoid approach in their series including 11 cases. Five cases had a bilateral SSLR defect, and the authors repaired these defects within the same operation session. All cases had MEC, and a peroperative spinal catheter was inserted in all cases. The authors obtained a success rate of 92%, whereas only 1 case required reoperation. They applied PNSF in 2 cases. They did not encounter any complications. Apart from these, various numbers of reports with endoscopic approach to SSLR CSF leak including fewer than 10 patients exist, which mention similar clinical findings, surgical techniques, and outcomes.[16,27-35] In our study, we obtained a high success rate as 85% after the first operation that increased to 100% after the second endoscopic attempt (**Table 3**).[1,21-26]

Minimal EETPA: As Applied to Lateral Recess CSF Leaks

The transpterygoid approach, which was first described to be used for pterygopalatine fossa, has been modified in time to be applied to other anatomical localizations.[36] Bolger[27] was the first to use this approach for the treatment of SSLR CSF leak. Kasemsiri et al.[7] classified endoscopic transpterygoid approaches in 5 types (types A to E). In this classification, type A involves a partial removal of the medial and/or lateral pterygoid plates; type B involves the removal of the medial and anterior aspect of the base of the pterygoid process; type C involves dissecting the vidian nerve to identify the petrous internal carotid artery and removing the base of the pterygoid plates; and type D involves a partial or complete removal of the pterygoid plates with dissection of the petrous internal carotid artery. In addition to performed removals in type D, type E involves the removal of the medial third of the Eustachian tube.

In the type B approach, the anterior aspect of the pterygoid bone floor is removed until the anterior orifice of the VC to reach the lateral recess. There is no need to remove the more lateral and inferior parts of pterygoid bone or to drill the undersurface of the VC to transpose the vidian nerve along its course. We applied this modification and tailored the amount of bone removal according to the pathology (i.e., the size of the MEC) in our cases, therefore, redefine this approach as the EEMTPA.

Facilitating tissue healing in the repair area is essential for the permanent treatment of CSF leak.[37] Since Hadad et al.[8] first described PNSF in 2006, this technique has been the backbone of reconstruction in almost all CSF leak cases. In addition, PMTF, an alternative to the PNSF acting in a similar fashion, is also used frequently.[38] A combination of these 2 techniques should be considered for cases with persistent rhinorrhea despite previous CSF leak surgery, or with high flow leak. Since all cases in our series had small skull base defects, we applied multilayer closure with tissue overlay grafts in accordance with the algorithm described by Alexander et al.[1]

In their article published in 2005, Kassam et al.[39] described balloon stent as a supporting modification to skull base reconstruction after endoscopic expanded endonasal surgery. Later, Cavallo et al.[40] also used inflated Foley balloon catheter (12–14 F) for reconstruction after endoscopic expanded transsphenoidal surgery. A similar study described a technique supporting reconstruction with a different balloon type.[41] However, no previous series related with SSLR CSF leak repair have applied balloon stent after the reconstruction stage.

Regardless of their etiology, CSF leaks originating from the lateral recess are treated with the same technique; therefore, they were examined in the same study. For the management of spontaneous CSF leak, it is possible to decide a treatment plan aiming to eliminate signs or cause of increased intracranial pressure in addition to the surgical procedure.[42] In the present study, we did not perform intracranial pressure monitoring for patients with spontaneous etiology, and surgical (ventriculoperitoneal shunt) or medical (acetazolamide) treatment was not administered in patients with possibly increased pressure. Despite this, the 100% success rate that we obtained presents an opinion for future studies that CSF leaks can be treated with appropriate and sufficient endoscopic surgery without the requirement for additional treatments aiming to reduce increased intracranial pressure.

CONCLUSIONS

It is possible to operate many skull base pathologies with endoscopic endonasal approaches. Moreover, they seem to be a better option for the treatment of skull base CSF leaks. EEMTPS is a modification that is particularly preferred for the treatment of SSLR CSF leaks, allowing repair with high success rate. In cases with sufficient SSLR pneumatization, it enables reaching the area of the lateral recess where MEC and CSF leak are located while preserving the vidian nerve and sphenopalatine artery. PNSF is a very useful supplement to the classical reconstruction techniques in repair of SSLR CSF leaks. We also think that known techniques such as the intrasphenoidal balloon stent may be useful in reconstruction of this area.

REFERENCES

1. Alexander NS, Chaaban MR, Riley KO, Woodworth BA. Treatment strategies for lateral sphenoid sinus recess cerebrospinal fluid leaks. *Arch Otolaryngol Head Neck Surg*. 2012;138:471-478.
2. Isler C, Lyutviev Ahmedov M, Akgun MY, Kucukyuruk B, Gazioglu N, Sanus GZ, et al. Endoscopic endonasal cerebrospinal fluid leak repair on the ventral midline skull base: a single neurosurgical center experience. *Turk Neurosurg*. 2018;28:193-203.
3. Pagella F, Pusateri A, Matti E, Zoia C, Benazzo M, Gaetani P, et al. Endoscopic management of spontaneous clival cerebrospinal fluid leaks: case series and literature review. *World Neurosurg*. 2016; 86:470-477.
4. Banks CA, Palmer JN, Chiu AG, O'Malley BW, Woodworth BA, Kennedy DW. Endoscopic closure of CSF rhinorrhea: 193 cases over 21 years. *Otolaryngol Head Neck Surg*. 2009;140:826-833.
5. Marshall AH, Jones NS, Robertson JJ. An algorithm for the management of CSF rhinorrhea illustrated by 36 cases. *Rhinology*. 1999;37:181-185.
6. Selcuk H, Albayram S, Ozer H, Ulus S, Sanus GZ, Kaynar MY, et al. Intrathecal gadolinium-enhanced MR cisternography in the evaluation of CSF leakage. *AJNR Am J Neuroradiol*. 2010;31:71-75.
7. Kasemsiri P, Solares CA, Carrau RL, Prosser JD, Prevedello DM, Otto BA, et al. Endoscopic endonasal transpterygoid approaches: anatomical landmarks for planning the surgical corridor. *Laryngoscope*. 2013;123:811-815.
8. Hadad G, Bassagasteguy L, Carrau RL, Mataza JC, Kassam A, Snyderman CH, et al. A novel reconstructive technique after endoscopic expanded endonasal approaches: vascular pedicle nasoseptal flap. *Laryngoscope*. 2006;116:1882-1886.
9. Hammer G, Radberg C. The sphenoidal sinus. An anatomical and roentgenologic study with reference to transsphenoid hypophysectomy. *Acta Radiol*. 1961;56:401-422.
10. Wang J, Bidari S, Inoue K, Yang H, Rhoton A. Extensions of the sphenoid sinus: a new classification. *Neurosurgery*. 2010;66:797-816.
11. Vaezi A, Cardenas E, Pinheiro-Neto C, Paluzzi A, Branstetter BF 4th, Gardner PA, et al. Classification of sphenoid sinus pneumatization: relevance for endoscopic skull base surgery. *Laryngoscope*. 2015;125:577-581.
12. Woodworth BA, Prince A, Chiu AG, Cohen NA, Schlosser RJ, Bolger WE, et al. Spontaneous CSF leaks: a paradigm for definitive repair and management of intracranial hypertension. *Otolaryngol Head Neck Surg*. 2008;138:715-720.
13. Badia L, Loughran S, Lund V. Primary spontaneous cerebrospinal fluid rhinorrhea and obesity. *Am J Rhinol*. 2001;15:117-119.
14. Alexander A, Mathew J, Varghese AM, Ganesan S. Endoscopic repair of CSF fistulae: a ten year experience. *J Clin Diagn Res*. 2016;10:1-4.
15. Schlosser RJ, Bolger WE. Significance of empty sella in cerebrospinal fluid leaks. *Otolaryngol Head Neck Surg*. 2003;128:32-38.
16. Lai SY, Kennedy DW, Bolger WE. Sphenoid encephaloceles: disease management and identification of lesions within the lateral recess of the sphenoid sinus. *Laryngoscope*. 2002;112:1800-1805.
17. Hooper AC. Sphenoidal defects—a possible cause of cerebrospinal fluid rhinorrhoea. *J Neurol Neurosurg Psychiatry*. 1971;34:739-742.
18. Bendersky DC, Landriel FA, Ajler PM, Hem SM, Carrizo AG. Sternberg's canal as a cause of encephalocele within the lateral recess of the sphenoid sinus: areport of two cases. *Surg Neurol Int*. 2011;2:171.
19. Illing E, Schlosser RJ, Palmer JN, Curé J, Fox N, Woodworth BA. Spontaneous sphenoid lateral recess cerebrospinal fluid leaks arise from intracranial hypertension, not Sternberg's canal. *Int Forum Allergy Rhinol*. 2014;4:246-250.
20. Barañano CF, Curé J, Palmer JN, Woodworth BA. Sternberg's canal: fact or fiction? *Am J Rhinol Allergy*. 2009;23:167-171.
21. Tosun F, Carrau RL, Snyderman CH, Kassam A, Celin S, Schaitkin B. Endonasal endoscopic repair of cerebrospinal fluid leaks of the sphenoid sinus. *Arch Otolaryngol Head Neck Surg*. 2003;129:576-580.
22. Zoli M, Farneti P, Ghirelli M, Giulioni M, Frank G, Mazzatenta D, et al. Meningocele and meningoencephalocele of the lateral wall of sphenoidal sinus: the role of the endoscopic endonasal surgery. *World Neurosurg*. 2016;87:91-97.
23. Janakiram TN, Subramaniam V, Parekh P. Endoscopic endonasal repair of sphenoid sinus cerebrospinal fluid leaks: our experience. *Indian J Otolaryngol Head Neck Surg*. 2015;67:412-416.
24. Castelnuovo P, Dallan I, Pistochini A, Battaglia P, Locatelli D, Bignami M. Endonasal endoscopic repair of Sternberg's canal cerebrospinal fluid leaks. *Laryngoscope*. 2007;117:345-349.
25. Kirtane MV, Lall A, Chavan K, Satwalekar D. Endoscopic repair of lateral sphenoid recess cerebrospinal fluid leaks. *Indian J Otolaryngol Head Neck Surg*. 2012;64:188-192.
26. Tabaee A, Anand VK, Cappabianca P, Stamm A, Esposito F, Schwartz TH. Endoscopic management of spontaneous meningoencephalocele of the lateral sphenoid sinus. *J Neurosurg*. 2010;112: 1070-1077.
27. Bolger WE. Endoscopic transpterygoid approach to the lateral sphenoid recess: surgical approach and clinical experience. *Otolaryngol Head Neck Surg*. 2005;133:20-26.
28. Forer B, Sethi DS. Endoscopic repair of cerebrospinal fluid leaks in the lateral sphenoid sinus recess. *J Neurosurg*. 2010;112:444-448.
29. Schuknecht B, Simmen D, Briner HR, Holzmann D. Nontraumatic skull base defects with spontaneous CSF rhinorrhea and arachnoid herniation: imaging findings and correlation with endoscopic sinus surgery in 27 patients. *AJNR Am J Neuroradiol*. 2008;29:542-549.
30. El-Tarabishi MN, Fawaz SA, Sabri SM, El-Sharnobi MM, Sweed A. A modification of endoscopic endonasal approach for management of encephaloceles in sphenoid sinus lateral recess. *Eur Arch Otorhinolaryngol*. 2016;273:4305-4314.
31. Schmidt RF, Choudhry OJ, Raviv J, Baredes S, Casiano RR, Eloy JA, et al. Surgical nuances for the endoscopic endonasal transpterygoid approach to lateral sphenoid sinus encephaloceles. *Neurosurg Focus*. 2012;32:E5.
32. Pasquini E, Sciarretta V, Farneti G, Mazzatenta D, Modugno GC, Frank G. Endoscopic treatment of encephaloceles of the lateral wall of the sphenoid sinus. *Minim Invasive Neurosurg*. 2004;47:209-213.
33. Ajlan A, Achrol A, Soudry E, Hwang PH, Harsh G. Spontaneous sphenoid wing meningoencephaloceles with lateral sphenoid sinus extension: the endoscopic transpterygoid approach. *J Neurol Surg B Skull Base*. 2014;75:314-323.
34. Tomazic PV, Stammberger H. Spontaneous CSF-leaks and meningoencephaloceles in sphenoid sinus by persisting Sternberg's canal. *Rhinology*. 2009;47:369-374.
35. Melo NA, Borges BB, Magliarelli Filho PA, Godoy MD, Pereira LV, Pinna FR, et al. Lateral sphenoid sinus recess cerebrospinal fluid leak: a case series. *Eur Arch Otorhinolaryngol*. 2014;271: 2587-2594.
36. Yumoto E, Okamura H, Yanagihara N. Transmandibular transpterygoid approach to the nasopharynx, parapharyngeal space, and skull base. *Ann Otol Rhinol Laryngol*. 1992;101:383-389.
37. Patel MR, Stadler ME, Snyderman CH, Carrau RL, Kassam AB, Germanwala AV, et al. How to choose? Endoscopic skull base reconstructive options and limitations. *Skull Base*. 2010;20:397-403.
38. Simal Julián JA, Miranda Lloret P, Cárdenas Ruiz-Valdepeñas E, Barges Coll J, Beltrán Giner A, Botella Asunción C. Middle turbinate vascularized flap for skull base reconstruction after an

expanded endonasal approach. *Acta Neurochir (Wien)*. 2011;153:1827-1832.

39. Kassam A, Carrau RL, Snyderman CH, Gardner P, Mintz A. Evolution of reconstructive techniques following endoscopic expanded endonasal approaches. *Neurosurgic focus*. 2005;19:E8.

40. Cavallo LM, Messina A, Esposito F, de Divitiis O, Dal Fabbro M, de Divitiis E, et al. Skull base reconstruction in the extended endoscopic transsphenoidal approach for suprasellar lesions. *J Neurosurg*. 2007;107:713-720.

41. Amit M, Abergel A, Gil Z. Tetrahedral silicon balloon for endoscopic skull base reconstruction. *Laryngoscope*. 2012;122:973-976.

42. Woodworth BA, Palmer JN. Spontaneous cerebrospinal fluid leaks. *Curr Opin Otolaryngol Head Neck Surg*. 2009;17:59-65.

Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received 25 March 2018; accepted 27 June 2018

Citation: World Neurosurg. (2018) 118:e473-e482.
https://doi.org/10.1016/j.wneu.2018.06.219

*Journal homepage: **www.WORLDNEUROSURGERY.org***

*Available online: **www.sciencedirect.com***