original article

One Thousand Endoscopic Skull Base Surgical Procedures Demystifying the Infection Potential: Incidence and Description of Postoperative Meningitis and Brain Abscesses

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background. Endonasal endoscopic skull base surgery (ESBS) is perceived as having a high risk of infection because it is performed through the sinuses, which are not sterile.

objective. To identify the bacteriological characteristics, incidence, mortality, and risk factors for intracranial infection after ESBS.

methods. A retrospective analysis of the first 1,000 ESBS procedures performed at the University of Pittsburgh Medical Center from 1998 to 2008.

results. In 18 cases (1.8%), the patient developed meningitis. In 2 cases, the patient died within 2 months after surgery, of noninfectious causes. In 11 cases, cerebrospinal fluid (CSF) cultures had positive results. There were no predominant pathogens. Male sex (odds ratio [OR], 3.97 [95% confidence interval {CI}, 1.21–13.03]; $P = .02$), history of a craniotomy or endonasal surgery (OR, 4.77 [95% CI, 1.68–13.56]; $P = .003$), surgery with higher levels of complexity (OR, 6.60 [95% CI, 1.77–24.70]; $P = .005$), the presence of an external ventricular drain or ventriculoperitoneal shunt at the time of surgery (OR, 6.38 [95% CI, 1.07–38.09]; $P = .04$), and postoperative CSF leak (OR, 12.99 [95% CI, 4.24–39.82]; $P < .001$) were risk factors for infection.

conclusion. The incidence of infection of 1.8% in ESBS is comparable to that in open craniotomy. The most important risk factor was a postoperative CSF leak. All patients recovered from their infection.

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In recent years, neurosurgeons and otolaryngologists have worked together to perform endoscopic endonasal surgery for brain lesions.[1,2] Historically, transsphenoidal surgery has been used for pituitary tumors, but other midline anterior skull base lesions, such as encephaloceles and meningiomas, require the use of a transcranial and/or transfacial approach. Some of these lesions are amenable to endoscopic skull base surgery (ESBS). Major postoperative concerns with transdural ESBS are the risk of cerebrospinal fluid (CSF) rhinorrhea and meningitis. The incidence of meningitis after traditional transsphenoidal surgery ranges from 0.7% to 3.1%,[3-5] and for open craniotomy it ranges from 0.9% to 2.5%.[6-9] The most common causes of postsurgical infection are *Staphylococcus aureus,* streptococcal species, Enterobacteriaceae, and *Pseudomonas aeruginosa.*[6,7,10]

The rate of infection after ESBS is not well known, and surgeons have been concerned that the use of this approach could involve a high risk of infection. This article addresses the incidence of infection, bacteriological characteristics, and risk factors for postoperative meningitis or abscess by reviewing 1,000 ESBS procedures at the University of Pittsburgh Medical Center (UPMC) in Pittsburgh, Pennsylvania.

methods

Subjects

This study was approved by the institutional review board of the UPMC. The records of patients who underwent ESBS at UPMC Presbyterian Hospital during the period from January 1998 through April 2008 were studied. ESBS was defined as endoscopic surgery performed through the sinuses with dissection of the skull base with or without transgression of the dura.[11,12] This study did not include procedures involving patients who underwent an open craniotomy during their hospitalization. If a patient underwent multiple surgical procedures during 1 month, only the first was evaluated. Three cases for which medical records were not available were excluded, leaving 1,000 ESBS procedures for analysis. Occur-

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rences of meningitis or brain abscesses during the first postsurgical year were detected by means of retrospective review of medical records.

Data Abstraction

ESBS procedures were categorized into 5 levels of complexity on the basis of anatomic and pathological conditions (Table 1).[2] Level I procedures were excluded from this study. The endoscopic approach was selected on the basis of the location of the tumor. A transsphenoidal approach, the most basic approach for ESBS, was usually used for pituitary surgery. Other approaches, including transcribriform, transodontoid, and transclival approaches, were considered expanded approaches.

For each surgical procedure, we recorded the patient's age, sex, previous surgical procedures (endonasal procedures or craniotomies), prior radiation therapy, concurrent infection requiring antibiotics, type of endoscopic approach, level of complexity of the surgery,[2] duration of surgery (<4 hours or ⩾4 hours),[9] lumbar drain placement immediately after surgery, surgical indication, presence of ventriculoperitoneal (VP) shunt or external ventricular drain (EVD) at the time of surgery, VP shunt or EVD placement after surgery, the presence of any postoperative CSF leak, and the need for reoperation within the first postoperative month. Once infection was suspected, we collected data including CSF analysis, complete blood cell count, and all organisms that were identified by means of blood culture, CSF culture, and tissue culture, as well as what antibiotics were administered.

Ceftriaxone or cefepime was used for perioperative prophylaxis.[13] Vancomycin and aztreonam were administered to β-lactam–allergic patients. If the operation crossed the dura and the CSF was penetrated, antibiotic therapy was continued until the postoperative nasal packing was removed. Patients who had nasal packing without penetration of the dura received ampicillin-sulbactam or alternative antibiotics until the packing was removed. Antibiotics were discontinued after surgery for patients who did not receive nasal packing. Intravenous steroids were given perioperatively to some patients on the basis of serum cortisol levels, visual deficits, or cerebral edema.

A postoperative CSF leak was assessed if there was clear rhinorrhea and was confirmed with a β-2 transferrin test, as needed. In cases in which meningitis was suspected, CSF samples were collected via lumbar puncture or a neurosurgical drain and cultured. In cases in which a brain abscess was suspected, the site was aspirated and samples were cultured.

Centers for Disease Control and Prevention criteria[14] were used for the diagnosis of meningitis. A definitive diagnosis of infection required CSF cultures positive for a likely pathogen or a positive CSF Gram stain result. A diagnosis of possible infection required the following criteria to be met: (1) fever (temperature, ⩾38°C), headache, stiff neck, meningeal signs, cranial nerve signs, and/or irritability was present with no other recognized cause; (2) increased white blood cell count, elevated level of protein and/or decreased level of glucose in the CSF, and/or positive blood culture result was present; and (3) a full course of antibiotics was administered. If these symptoms and CSF abnormalities were present but a full course of antibiotics was not administered, the case was not included in the study. Guidelines for surgical-site infections[15] define a postneurosurgical infection as occurring within 30 days after the operation if no implant is left or within 1 year if an implant is in place and the infection seems to be related to the operation. Cases in which the patient recovered even though empirical antibiotic therapy was discontinued before the patient received a full course were excluded, as were cases in which the patient had an open intracranial wound at admission or underwent a craniotomy after the endonasal surgery and before the onset of infection. A diagnosis of a brain abscess was made if radiographic evidence of infection was present and organisms were cultured from samples of the site.

Statistical Analysis

Data are expressed as mean value ± standard deviation (SD) for continuous variables and as number and percentage for categorical variables. The χ^2 test, the Fisher exact test, and the Student t test were used for the comparisons when appropriate. A multivariable logistic regression model with stepwise selection was used to select factors that were significantly associated with meningitis. Analyses were performed with SAS, version 9.1 (SAS Institute), and all P values of .05 or less were considered to reveal a significant difference.

RESULTS

Patient Population

Of the 1,000 procedures analyzed, 501 (50.1%) were performed for male patients, and the mean age (±SD) was

table 1. Levels of Complexity of Endoscopic Skull Base Surgery

Level	Procedures	Example(s)
I	Basic sinonasal surgery (not skull base surgery)	Sphenopalatine artery ligation
II	Pituitary surgery	Removal of simple pituitary adenoma, repair of cerebrospinal fluid leak
III	Extrasellar extradural surgery	Optic nerve decompression, decompression of the odontoid for rheumatoid degeneration of C1 and C2
IV	Intradural skull base surgery	Craniopharyngioma, meningioma
V	Cerebrovascular surgery	Aneurysms, arteriovenous malformations, internal carotid artery dissection

TABLE 2. Indications for Endoscopic Skull Base Surgery

Indication	No. of cases: Involving noninfected patients (n = 982)	Involving infected patients (n = 18)
Cerebrospinal fluid leak	74	1
Optic nerve decompression	3	0
Benign invasive sinus disease	33	0
Benign neoplasms	577	14
Malignant neoplasms	182	3
Miscellaneous	113	0

49 ± 18 years. In 176 cases (17.6%), the patient had a history of endonasal surgery or craniotomy. In 185 cases (18.5%), the patient had a malignancy (Table 2), and in 28 cases (2.8%), the patient had received prior radiation therapy. The duration of surgery was 4 hours or longer for 361 procedures (36.1%). The 1,000 procedures included 476 categorized as level II surgery, 190 categorized as level III surgery, 227 categorized as level IV surgery, and 107 categorized as level V surgery. Of the 140 cases (14.0%) in which the patient had a postoperative CSF leak, 30 required treatment with a lumbar drain alone and 110 required endoscopic repair. The incidence of postoperative CSF leakage was 10.7% (51 of 476) in level II procedures, 3.7% (7 of 190) in level III, 34.4% (78 of 227) in level IV, and 3.7% (4 of 107) in level V.

Incidence of Infection

Postoperative intracranial infections occurred after 18 procedures (Table 3). Culture results were positive in 11 cases (Table 3; cases 1–11) and negative in 7 cases (Table 3; cases 12–18). In 2 cases, brain abscesses developed in patients who underwent surgery that did not involve the placement of implants. Although possibly related to the surgical procedures, these infections could not be classified as postsurgical infection, because they occurred more than 30 days after surgery (56 and 653 days after surgery). The incidences of infection were as follows: 0.6% (3 of 476) in level II procedures, 0% (0 of 190) in level III, 6.2% (14 of 227) in level IV, and 0.9% (1 of 107) in level V.

Symptoms and Signs

The patient's symptoms were not documented in 1 case of infection. The most common symptoms were headache, fever, and altered mental status, which occurred in 10 of 17 cases (58.9%). The patient experienced nausea and vomiting in 8 cases (47.1%), photophobia in 5 cases (29.4%), nuchal rigidity in 4 cases (23.5%), and seizure in only 1 case.

Microbiological Findings and Treatment

CSF cultures or Gram staining yielded positive results in 11 cases (Table 3; cases 1–11). Among cases of meningitis, *Enterococcus faecalis* was cultured from the patient's CSF in 2 cases. Diphtheroids, *Stenotrophomonas maltophilia, Bacillus cereus, Candida albicans, Serratia marcescens, P. aeruginosa,* viridans group streptococci, and coagulase-negative staphylococci were detected in 1 case each. All patients with clinical evidence of meningitis were treated with extended courses of appropriate antimicrobials.

Complications and Outcomes

In 11 cases, the patient recovered from meningitis without any other complications (cases 1, 2, 3, 4, 7, 9, 10, 14, 15, 16, and 18). In 2 cases, the patient died of noninfectious causes within 2 months after surgery. In case 8, the patient sustained a cardiac arrest with respiratory failure, and in case 11, the patient experienced a large midline intracranial bleed after receiving anticoagulant therapy for a pulmonary embolism. Patients developed other nonfatal complications in 5 cases (cases 5, 6, 12, 13, and 17), including intracranial hemorrhage, embolic stroke, seizure, pulmonary embolism, deep vein thrombosis, respiratory failure, infections at other sites, and adrenal insufficiency. Neurological deficits persisted in only 2 cases (cases 5 and 12).

Lumbar Drain Placement Immediately after Surgery

Lumbar drains were placed for patients who had copious CSF leaks, opening of the third ventricle, wide dissection of the arachnoid membranes, or excessive amounts of blood in the cistern. There was a low threshold for inserting a lumbar drain in obese patients. Following 127 procedures (12.7%), a lumbar drain was placed for the patient immediately after surgery. In 7 (5.5%) of these 127 cases, infections occurred (Table 4).

Presence of VP Shunt or EVD at the Time of Surgery

In 13 cases (1.3%), the patient had a VP shunt in place prior to hospitalization; in 2 (15.4%) of these cases, a postoperative infection developed (Table 4). In both of these cases (cases 6 and 11), the shunt had been placed for hydrocephalus, but the reasons for placement of a VP shunt were not documented in all cases.

VP Shunt or EVD Placement after Surgery

In 51 cases (5.1%), an EVD or VP shunt was placed for the patient after ESBS. Infection occurred in 5 (9.8%) of these 51 cases (Table 4). In cases 5 and 12, the patient experienced refractory CSF leakage, so a VP shunt or EVD was placed for CSF diversion. In case 9, a VP shunt was placed to treat the patient's hydrocephalus. In cases 6 and 11, the patient had a VP shunt in place prior to hospitalzation that was removed as a result of possible infection.

Postoperative CSF Leak

In 140 cases (14.0%), the patient experienced a postoperative CSF leak, and in 13 (9.3%) of these 140 cases, an infection

TABLE 3. Characteristics of 18 Case Patients with Infection after Endoscopic Skull Base Surgical Procedures

Case patient	Age in years, sex	Level of surgery	Disease	Day of onset: Of CSF leak	Day of onset: Of symptoms	Serum WBC count, cells × 10^9 per L (% neutrophils)	CSF level: WBCs per mm^3 (% neutrophils)	CSF level: Protein, mg/dL	CSF level: Glucose, mg/dL	Gram staining and culture findings	Antibiotic(s) used
1	59, M	IV	Craniopharyngioma	7	7	12.8 (77)	64 (37)	64	54	Diphtheroids	Vancomycin
2	18, M	IV	Pituitary adenoma	14	14	20.7 (80)	1,440 (81)	139	57	*Stenotrophomonas maltophilia*	Levofloxacin, TMP-SMZ
3	63, M	IV	Pituitary adenoma	None	4	16.1 (88)	23,500 (90)	295	43	*Bacillus cereus*	Vancomycin
4	27, F	II	Pituitary adenoma	3	3	7.7 (82)	2,530 (64)	125	30	*Enterococcus faecalis*	Ampicillin, gentamicin
5	48, M	IV	Meningioma	4	21	8.3 (73)	13,200 (73)	293	28	*Candida albicans*	Fluconazole
6	65, M	IV	Meningioma	3	5	14.3 (70)	276 (100)	51	87	*Serratia marcescens*	Meropenem
7	52, F	IV	Pituitary adenoma	None	1	17.4 (87)	22,100 (86)	264	60	Gram-negative rods[a]	Cefepime
8	56, M	IV	Malignant sinus disease	5	1	22.9 (89)	3,190 (70)	272	49	*Pseudomonas aeruginosa*	Cefepime, ciprofloxacin
9	27, M	IV	Meningioma	2	15	12.4 (89)	571 (94)	204	72	*E. faecalis*	Ampicillin
10	48, M	IV	Meningioma	4	6	10.1 (89)	10,500 (65)	233	27	Viridans streptococci	Vancomycin
11	66, M	II	Pituitary adenoma	None	12	25.0 (95)	924 (85)	685	47	CoNS	Linezolid
12	43, M	IV	Meningioma	4	8	15.6 (88)	3,200 (92)	252	98	Negative	Cefepime, vancomycin
13	76, M	IV	Metastasis	14	14	8.4 (72)	90 (91)	294	85	Negative	Ceftriaxone, cefepime, vancomycin
14	76, F	II	CSF leak	None	2	14.7 (84)	13 (8)	69	72	Negative	Vancomycin
15	49, M	IV	Craniopharyngioma	10	30	18.4 (78)	17,573 (80)	53	44	Negative	Cefepime, metronidazole, vancomycin
16	45, M	IV	Meningioma	9	6	12.4 (75)	1,544 (83)	179	24	Negative	Meropenem, vancomycin
17	14, M	V	Angiofibroma	None	10	16.4 (90)	2,970 (81)	102	50	Negative	Cefepime, vancomycin
18	29, M	IV	Chondroma	22	2	14.5 (91)	13,500 (75)	249	49	Negative	Cefepime, vancomycin

NOTE. In cases 5, 6, 9, 11, and 12, an external ventricular drainage or ventriculoperitoneal shunt was placed for the patient after surgery. CoNS, coagulase-negative staphylococci; CSF, cerebrospinal fluid; F, female; M, male; TMP-SMZ, trimethoprim-sulfamethoxazole; WBC, white blood cell.

[a] Gram-negative rods were seen on Gram stain; however, no organism grew in cultures.

TABLE 4. Risk Factors for Infection after Endoscopic Skull Base Surgery in Univariable Analysis

Risk factors	No. (%) of cases: Involving noninfected patients ($n = 982$)	No. (%) of cases: Involving infected patients ($n = 18$)	P
Male sex	487 (49.6)	14 (77.8)	.02
Age, years, mean (range)	49.2 (3–96)	48.1 (14–76)	.80
History of endonasal surgery or craniotomy	167 (17.0)	9 (50.0)	.002
Malignancy	182 (18.5)	3 (16.7)	>.99
Prior radiation therapy	26 (2.6)	2 (11.1)	.09
Concomitant infection requiring antibiotics	17 (1.7)	0 (0)	>.99
Duration of surgery ⩾4 hours	349 (35.5)	12 (66.7)	.009
Level of complexity of surgery[a]			<.001
II	473 (48.2)	3 (16.7)	
III	190 (19.3)	0 (0)	
IV	213 (21.7)	14 (77.8)	
V	106 (10.8)	1 (5.6)	
Lumbar drain placement immediately after surgery	120 (12.2)	7 (38.9)	.004
Early reoperation	74 (7.5)	3 (16.7)	.16
Presence of EVD or VP shunt at surgery	11 (1.1)	2 (11.1)	.02
EVD or VP shunt placed after surgery	46 (4.7)	5 (27.8)	.002
Postoperative cerebrospinal fluid leak	127 (12.9)	13 (72.2)	<.001
Type of approach			
Transsphenoidal	424 (43.2)	10 (55.6)	Reference
Transcribriform	137 (14.0)	1 (5.56)	.48
Transplanum	125 (12.7)	3 (16.7)	>.99
Transodontoid	16 (1.6)	0 (0)	>.99
Transclival	81 (8.2)	1 (5.6)	>.99
Combined sagittal plane	17 (1.7)	2 (11.1)	.09
Transorbital	42 (4.3)	0 (0)	>.99
Midcoronal plane	140 (14.3)	1 (5.6)	.31

NOTE. EVD, external ventricular drain; VP, ventriculoperitoneal.
[a] Levels IV and V were compared with levels II and III.

developed. Overall, of 18 cases of infection, 13 (72.2%) occurred in a patient with a postoperative CSF leak ($P < .001$) (Table 4). The mean time to onset of postoperative CSF leakage was 6.9 days (range, 1–33 days; SD, 5.7 days) in cases in which the patient did not have an infection and 8.4 days (range, 2–22 days; SD, 5.7 days) in cases in which the patient had an infection ($P = .24$). Among the 13 cases of infection that occurred in a patient with a CSF leak, in 6 cases the patient developed a CSF leak prior to meningitis, in 4 cases the patient developed a postoperative CSF leak and symptoms of meningitis on the same day, and in 3 cases the patient developed meningitis prior to a postoperative CSF leak.

For all 13 cases of postoperative CSF leaks in infected patients, treatment involved endoscopic repair, whereas for 30 (23.6%) of 127 cases of postoperative CSF leaks in noninfected patients, treatment consisted of only the placement of a lumbar drain. In the remaining cases, the patient was treated with endoscopic repair.

Risk Factors

According to univariable analysis (Table 4), male sex, history of surgery (craniotomy or endonasal surgery), long duration of surgery (⩾4 hours), procedures with a higher level of complexity (level IV or V), lumbar drain placement immediately after surgery, the presence of an EVD or VP shunt at the time of surgery, EVD or VP shunt placement after surgery, and postoperative CSF leak were risk factors for infection. Age, malignancy, prior radiation therapy, concomitant infection, and the use of any expanded approach (transcribriform, transplanum, transodontoid, transclival, combined sagittal plane, transorbital, or midcoronal plane) were not risk factors. According to the multivariable logistic regression model (Table 5), male sex, history of surgery (craniotomy or endonasal surgery), procedures with a higher level of complexity (level IV or V), the presence of an EVD or VP shunt at the time of surgery, and postoperative CSF leak were risk factors.

TABLE 5. Risk Factors for Intracranial Infection after Endoscopic Skull Base Surgery in Multivariable Logistic Regression Model

Variable	P	OR (95% CI)
Male sex	.02	3.97 (1.21–13.03)
History of craniotomy or endonasal surgery	.003	4.77 (1.68–13.56)
Surgery with higher level of complexity (level IV or V)	.005	6.60 (1.77–24.70)
Presence of EVD or VP shunt at surgery	.04	6.38 (1.07–38.09)
Postoperative CSF leak	<.001	12.99 (4.24–39.82)

NOTE. CI, confidence interval; CSF, cerbrospinal fluid; EVD, external ventricular drain; OR, odds ratio; VP, ventriculoperitoneal.

DISCUSSION

This study sheds light on the risk of postoperative infections after ESBS, a relatively new procedure with limited data available regarding outcomes and morbidity. The main advantages of this approach are a quick recovery and decreased manipulation of brain tissue to access deep areas that would be difficult to reach using traditional approaches. The administration of antibiotics prior to culture sampling can complicate the diagnosis of postoperative meningitis. CSF findings may result from inflammatory reactions to surgery or to an EVD. The postoperative incidence of infection was uncertain. We document an incidence of 1.8% in this study, and in no case did a patient die as a direct consequence of meningitis, which is comparable to the results found with other approaches.

The incidence of postoperative meningitis after transsphenoidal surgery for pituitary adenomas without intradural involvement has been reported as 0.7%–3.1%,[3-5] which is comparable to our 0.6% incidence in level II procedures. Level IV and V lesions have historically been treated with skull base craniotomies and the use of transfacial approaches. Previous studies have shown the incidence of postoperative meningitis after a standard craniotomy to be 0.9%–2.5%[6-9] and after skull base procedures to be 2.0%–4.8%.[16,17] Previously, Donald[16] showed a 4.8% incidence of meningitis in patients with malignant skull base tumors. Kryzanski et al[17] reported that 1 patient (2%) developed meningitis among 58 cases of midline anterior skull base pathology treated with a craniotomy or the use of a craniofacial approach. These findings are also comparable to the incidences of meningitis encountered in this study (6.2% with level IV procedures and 0.9% with level V procedures).

Procedures involving the endoscopic endonasal approach are considered to be "clean-contaminated" procedures, because the sinonasal cavities are adjacent to the intracranial compartment and many instruments and graft materials pass through this potentially contaminated field during ESBS. Despite this, we observed few infections. Low incidences of infection could be promoted by the constant irrigation of the surgical site with sterile saline. In addition, the lower concentration of bacteria in the sinonasal cavity, compared with the mouth, may partly explain why the incidence of infection with endonasal surgery is much lower than that with transoral surgery.[18]

Male sex, history of surgery (craniotomy or endonasal surgery), procedures with higher levels of complexity (level IV or V), the placement of an EVD or VP shunt prior to hospitalization, and postoperative CSF leakage were identified as possible risk factors with use of a multivariable logistic regression model. The most important risk factor was a postoperative CSF leak. The duration of surgery, the level of complexity, the placement of a lumbar drain immediately after surgery, early reoperation, the placement of an EVD or VP shunt after surgery, and the use of expanded approaches could be confounding factors for postoperative CSF leakage. However, CSF leakage is already a known risk factor for meningitis in patients with head trauma as well. Meningitis develops in 7%–30% of cases of posttraumatic CSF leakage, and the incidence of infection increases with the duration of the CSF leak.[19]

The incidence of postoperative CSF leakage in level IV procedures was 34.4%; in contrast, that in level V procedures was 3.7%. Although both level IV and V procedures are intradural, level IV procedures involve the brain parenchyma, whereas level V procedures are mainly vascular procedures, so the increased incidence of leakage with level IV procedures is an expected finding. The incidence of postoperative CSF leakage in previous studies of transsphenoidal surgery ranges from 2%[1] to 13%.[20] The incidence of postoperative CSF leakage after craniotomy for skull base lesions ranges from 13%[21] to 29%.[22] The incidence of postoperative CSF leakage after ESBS with procedures similar to our level IV procedures ranges from 20% to 33%,[23-25] which resembles our findings.

In our study, an intracranial infection occurred in 13 (9.3%) of 140 cases in which the patient experienced a postoperative CSF leak, all in cases in which the patient had substantial leaks requiring endoscopic repair. In no case did a patient with a small leak (amenable to management with a lumbar drain alone) have infection, which suggests that patients with refractory postoperative CSF leaks have a high risk of infection. The prevention and management of postoperative CSF leaks may therefore be extremely important.

In 2006, a pedicled nasal septal flap (the Hadad-Bassagasteguy flap) for vascularized reconstruction of dural defects[12,26-28] was introduced, after which the incidence of postoperative CSF leakage decreased to less than 10% for level IV procedures. The incidence of postoperative infections among level IV patients decreased from 11.5% to 2.4% ($P < .01$).

In summary, despite the concerns about passing through the nasal passages and sinuses, the incidence of postoperative meningitis and brain abscesses after ESBS is similar to that for other surgical approaches. Expanded endonasal approaches, including those accessing the subarachnoid space (level IV), are comparable in safety to standard approaches to the skull base. Preventing CSF leaks is extremely important in preventing infectious complications of ESBS.

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