The Endoscopic Endonasal Approach to Repair of Iatrogenic and Noniatrogenic Cerebrospinal Fluid Leaks and Encephaloceles of the Anterior Cranial Fossa

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Key words
- Anterior skull base
- Endoscopic
- Minimal access
- Minimally invasive
- Spontaneous CSF leak
- Traumatic CSF leak

Abbreviations and Acronyms
BIH: Benign intracranial hypertension
BMI: Body mass index
CSF: Cerebrospinal fluid
CT: Computerized tomography
FESS: Functional endoscopic sinus surgery
HRCT: High resolution CT
ICP: Intracranial pressure
MRI: Magnetic resonance imaging
VP: Ventriculoperitoneal


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Citation: World Neurosurg. (2014) 82, 6S:S86-S94. http://dx.doi.org/10.1016/j.wneu.2014.07.018

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

OBJECTIVE: **The current approach for the diagnosis and repair of spontaneous and traumatic anterior skull-base defects is oulined, highlighting the controversies that exist in the field and describing the strategies required to access different segments of the anterior cranial fossa.**

METHODS: **We reviewed the literature concerning endoscopic management of anterior skull-base defects. These publications have been combined with our own experience repairing cerebrospinal fluid (CSF) leaks and encephaloceles that developed spontaneously, traumatically, or intentionally as a result of endoscopic skull-base surgery.**

RESULTS: **We present a systematic methodology for the repair of these defects. We have divided our surgical approach into four separate corridors. These are the transnasal, transsphenoidal, transethmoidal, and transmaxillary corridors. Dissection strategies vary for each corridor, but with a combination of approaches, all areas of the anterior skull base can be accessed. Skull-base defects are successfully repaired with a multilayered closure that often involves use of a vascularized pedicled mucosal flap. Adoption of this technique has decreased our rate of postoperative CSF leak from 5.9%—3.1%.**

CONCLUSIONS: **Endoscopic endonasal repair of CSF leaks and encephaloceles has evolved significantly during the past decade. The versatility of different endoscopic approaches through the four endonasal corridors allows for the endoscopic repair of almost all skull-base defects. The use of vascularized pedicled mucosal flaps has evolved to cover these defects as part of multilayered closure strategies.**

INTRODUCTION

Noniatrogenic cerebrospinal fluid (CSF) leaks occur commonly in the anterior cranial fossa. Iatrogenic CSF leaks can occur inadvertently during endoscopic sinus surgery and as a natural course of endoscopic skull-base surgery. For spontaneous CSF leaks, primary closure rates have improved from 70%—80% in the 1980s (16) to >90% with the evolution of endoscopic techniques (14, 23, 25, 30). As such, endoscopic endonasal repair of CSF leaks and encephaloceles has begun to replace traditional open craniotomy techniques. Closure rates for iatrogenic high-flow CSF leaks that occur during endoscopic skull-base surgery have improved from 20%—70% in early publications to <5% more recently (24, 25). This survey outlines the current approach for the diagnosis and repair of these defects, highlighting the controversies that exist in the field and describing the varied strategies required to access different segments of the anterior cranial fossa.

CLASSIFICATION OF CSF LEAKS

Noniatrogenic CSF leaks may be broadly classified into three categories: spontaneous, tumor-related, and traumatic. It is important to consider each category separately, as the management philosophy for each category differs based on an understanding of its cause.

Previously, spontaneous CSF leaks were a diagnosis of exclusion of other attributable causes. However, our understanding of their pathophysiology has evolved considerably. Current understanding holds that spontaneous CSF leaks are often associated with elevated intracranial pressure (ICP). The most likely cause of elevated ICP is benign intracranial hypertension (BIH), which can be diagnosed by the modified Dandy criteria (Table 1).

Seventy percent of patients with spontaneous CSF leaks are diagnosed with BIH based on these criteria (39). Spontaneous CSF leaks are frequently associated with encephalocele formation. Elevated ICP may cause encephalocele herniation through preexisting congenital skull-base defects, or it may cause attenuation of skull-base bone that results in a new defect. Among the congenital defects, 50% originate at the foramen cecum, whereas the remaining 50% occur near the cribriform plate or along the ethmoid roof (Figure 1). Far

Table 1. Modified Dandy Criteria

1. Symptoms of raised intracranial pressure (headache, nausea, vomiting, transient visual obscurations, or papilledema)
2. No localizing signs with the exception of abducens (sixth) nerve palsy
3. The patient is awake and alert
4. Normal CT/MRI findings without evidence of thrombosis
5. LP opening pressure of >25 cm H_2O and normal biochemical and cytologic composition of CSF
6. No other explanation for the increased intracranial pressure

CT, computerized tomography; MRI, magnetic resonance imaging; LP, lumbar puncture; CSF, cerebrospinal fluid.

lateral defects may occur due to improper fusion of Sternberg's canal, a phenomenon discussed later. In addition, these encephaloceles tend to be quite large, as increased ICP pushes intracranial contents through relatively small skull-base defects. Spontaneous CSF leaks are also highly associated with the female gender and obesity. In one series of 55 consecutive patients with spontaneous CSF leaks, 70% of patients were women and 46 of 55 patients were obese, with an average body mass index (BMI) of 36.2 kg/m^2. Elevated ICP persisted in these patients postoperatively, with an average lumbar drain pressure of 27 cm H_2O (39). In another series of 21 patients, 18 patients were women, with an average BMI of 31.2 kg/m^2 (40).

In many ways, spontaneous CSF leaks are the most difficult to treat. Small, slow leaks can be hard to locate. Broad attenuation of the bone of the skull base makes achieving a watertight closure difficult. Associated encephaloceles or meningoencephaloceles are found in 50%–100% of patients. Postoperative recurrence rates are generally higher compared with all other causes, ranging from 25%–87% in some series (16, 27, 30). Important, understanding the etiology and demographics of spontaneous CSF leaks is critical to successful primary closure. Although repair techniques are similar to the closure of other leak types, postoperative ICP management of these patients is critical. The details and controversies of postoperative ICP management will be discussed later.

Traumatic CSF leaks may be divided into iatrogenic and noniatrogenic leaks. Iatrogenic CSF leaks most commonly occur during transsphenoidal pituitary tumor resection (0.5%–15% incidence). They also frequently occur during acoustic neuroma surgery (7%–11% incidence) and during functional endoscopic sinus surgery (0.5%–3% incidence) (21). The most common sites of inadvertent skull base violation during endoscopic sinus surgery are the lateral lamella of the cribriform plate and the roof of the posterior ethmoid sinuses (3), as the skull base slopes inferiorly toward the face of the sphenoid sinuses (**Figure 2**). Of these leaks, 50% present intraoperatively or immediately postoperatively, whereas the remaining 50% are delayed, occurring 1 week to 1 month postoperatively. Theories for delayed iatrogenic CSF leak presentation include wound contraction, flap devascularization, or necrosis, resolving cerebral edema and increased ICP (21).

Traumatic noniatrogenic CSF leaks are usually due to accidental trauma (70%–80% incidence). Two to 4% of all acute head injuries result in CSF rhinorrhea. In 70% of cases, these leaks resolve spontaneously with observation or a lumbar drainage; however, repair should be considered if leaks do not resolve within 1–2 weeks to prevent meningitis (21).

Intracranial tumors may cause CSF leaks as well. Tumor growth may obstruct CSF reabsorption leading to increased ICP and a high pressure leak. Alternatively, intracranial or extracranial tumor growth may directly erode the skull base.

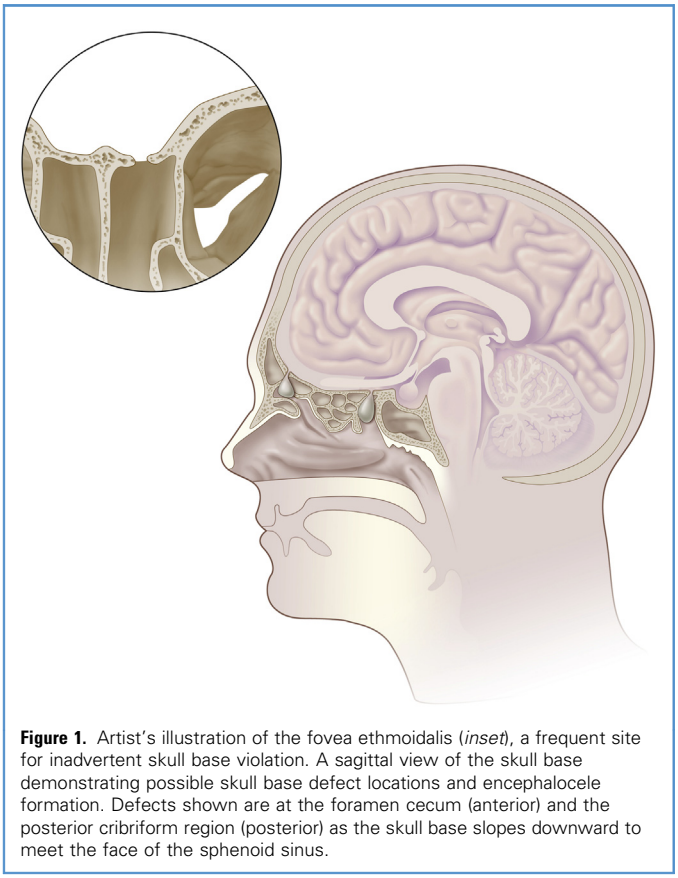

Figure 1. Artist's illustration of the fovea ethmoidalis (*inset*), a frequent site for inadvertent skull base violation. A sagittal view of the skull base demonstrating possible skull base defect locations and encephalocele formation. Defects shown are at the foramen cecum (anterior) and the posterior cribriform region (posterior) as the skull base slopes downward to meet the face of the sphenoid sinus.

LOCALIZING THE DEFECT

Preoperative and intraoperative localization of a CSF leak is an essential component of successful repair. There are several options for preoperative localization. High resolution CT (HRCT), CT cisternography, magnetic resonance imaging (MRI), MRI cisternography, and radionuclide cisternography will be discussed. HRCT is ideally noninvasive; it does not require any