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Endoscopic Management of Cerebrospinal Fluid Rhinorrhea

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History

Transcranial repair of cerebrospinal fluid (CSF) leak was first reported by Dandy, who closed a cranionasal fistula via frontal craniotomy in 1926. The first extracranial approach was described in 1948 by Dohlman, who used a naso-orbital incision to close an anterior skull base CSF leak. Transnasal approaches subsequently were used by Hirsch in 1952 and Vrabec and Hallberg in 1964. Improved instrumentation for sinus surgery led to the endoscopic repair of CSF leaks by Wigand in 1981. Since the 1980s, the minimally invasive endoscopic approach has gained widespread acceptance. The diagnostic aspects and surgical techniques have evolved, leading to higher success rates (approximately 90%) and lower morbidity than traditional intracranial techniques for most leaks. The endoscopic approach has become the standard of care [1,2].

Normal physiology

It is helpful to understand normal CSF physiology to diagnose and treat patients with CSF rhinorrhea properly. CSF is formed primarily in the choroid plexus within the lateral, third, and fourth ventricles at a rate of 0.35 mL/min (20 mL/h or 350–500 mL/d). The total volume of CSF in an adult is approximately 90 to 150 mL; the total volume of CSF is turned over three to five times each day [3].

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After production in the choroid plexus, CSF flows from the ventricular system into the subarachnoid space around the spinal cord and cerebral convexities. CSF absorption occurs along these convexities at the arachnoid villi. The villi project into the dural sinuses and act as one-way valves that typically require a pressure gradient of 1.5 to 7 cm H_2O for antegrade flow from the subarachnoid space into the dural sinuses. At lower pressure differentials, the villi close and prevent retrograde flow.

Normal CSF pressure is approximately 5 to 15 cm H_2O recorded in the lumbar cistern with the patient lying in the decubitus position. This pressure varies significantly depending on time of day, patient age, activity level, and cardiac and respiratory cycles. Neurologic symptoms may develop when pressures exceed 15 to 20 cm H_2O, and treatment to reduce intracranial pressure (ICP) generally is recommended for patients with mild-to-moderate elevations, even in the absence of symptoms [3].

Pathophysiology

Overview

CSF leaks can be categorized based on a variety of factors, such as etiology, anatomic site, or underlying ICP. The authors typically classify leaks based on etiology because this is usually apparent from the patient's clinical history, then take into account the impact that anatomic location and underlying ICP have on the surgical repair. All of these factors should be considered because they influence medical and surgical treatment and long-term success.

Accidental trauma

Historically, closed head injury secondary to accidental trauma is the most common etiology of CSF leaks. Leaks occur in approximately 1% to 3% of all closed head injuries (Fig. 1). These leaks usually begin within 2 days of the injury [4]. More than 70% close with observation or conservative treatment, such as bed rest or lumbar drain, but these nonsurgical closures probably result in closure with thin fibrous tissue or mucosa because dura mater does not regenerate [5]. Nonsurgical treatment has been associated with a significant incidence of ascending meningitis (30–40%) in long-term follow-up, despite leak cessation. More aggressive, early endoscopic repair may have a role in reducing this long-term risk of meningitis. Accidental traumatic CSF leaks are heterogeneous, and bony skull base defects can vary from a narrow crack in a blunt head injury, to multiple, comminuted cracks in projectile injuries.

Surgical trauma

The most common surgeries leading to iatrogenic skull base defects are functional endoscopic sinus surgery and neurologic surgery. Differences

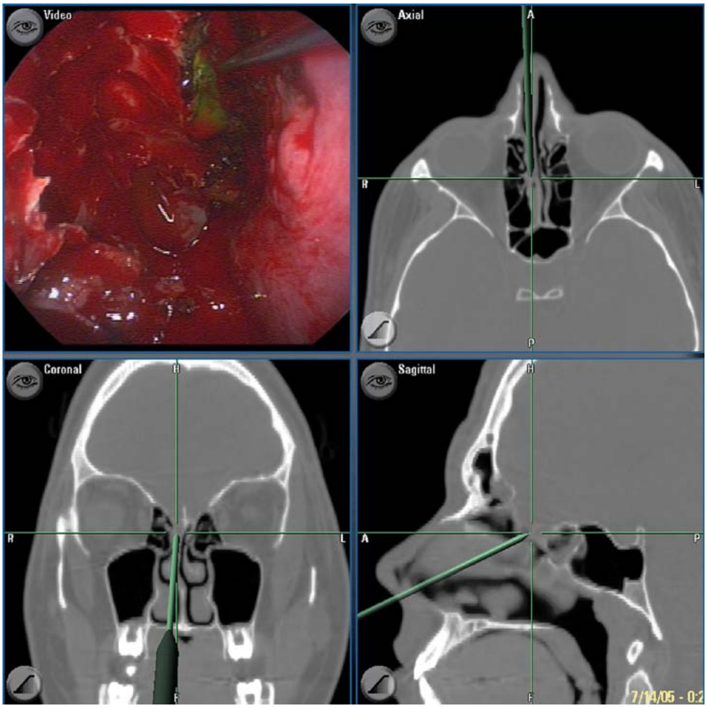

Fig. 1. Triplanar imaging of a closed head injury that resulted in a CSF leak and crack of the skull base that extended from the posterior table of the right frontal sinus to the face of the sphenoid along the olfactory cleft.

between accidental and surgical trauma may be the size of the bony defect and the degree of dural and associated brain parenchymal disruption. Iatrogenic defects typically occur during bone resection, often with powered instrumentation, and may result in bony defects 2 cm in size.

The two most common sites of skull base injury associated with functional endoscopic sinus surgery are the lateral lamella of the cribriform plate and the posterior ethmoid roof near the face of the sphenoid. Injury to the lateral lamella of the cribriform can occur during an approach to the anterior ethmoid or frontal recess or when resecting the middle turbinate close to the skull base (Fig. 2). The bone of the lateral lamella of the cribriform is usually thinner than the ethmoid roof and more susceptible to injury.

Iatrogenic posterior ethmoid defects typically occur in cases in which the maxillary sinus is highly pneumatized and expands superomedially, causing a corresponding and relative decrease in posterior ethmoid pneumatization. The superior-to-inferior dimension of the posterior ethmoid is reduced, narrowing the available surgical space before encountering the skull base.

CSF leak following neurologic surgery can occur after a variety of procedures, but the most common is pituitary surgery [6]. Disruption of the

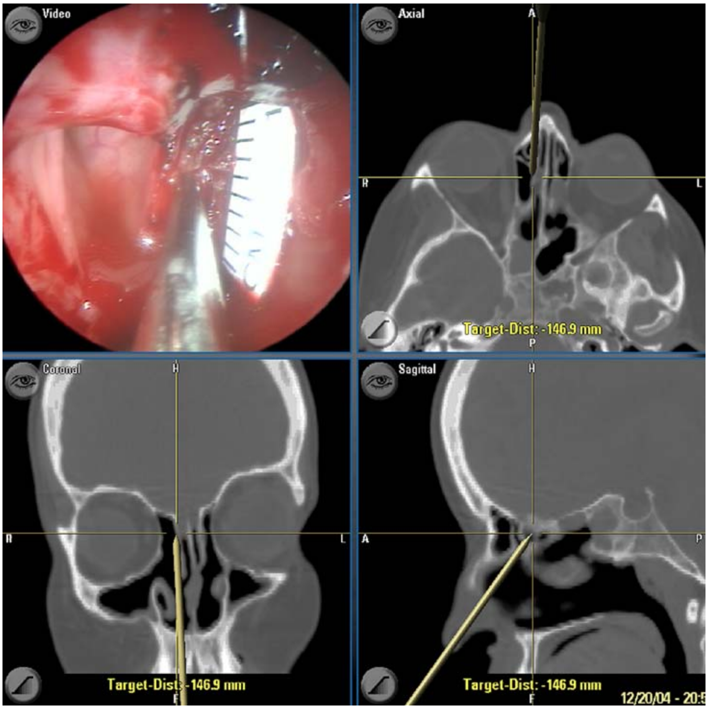

Fig. 2. Triplanar imaging of an iatrogenic CSF leak that occurred during functional endoscopic sinus surgery secondary to injury along the right lateral lamella.

sellar diaphragm by tumor or surgical trauma can result in a leak. Additionally, a misdirected approach for pituitary surgery that does not identify the sella properly can lead to an iatrogenic skull base defect. Other causes of CSF leak during neurosurgery include craniofacial resection and transcranial approaches.

Tumors

Skull base tumors can lead to CSF leaks directly or indirectly. Direct tumor invasion across the anterior skull base can cause large defects with significantly diseased or missing bone surrounding the defect (Fig. 3). These tumors can be primary central nervous system neoplasms that extend into the nasal cavity, or, conversely, they may be sinonasal primaries that extend intracranially. Treatments for the tumor itself, such as surgery, radiation, or chemotherapy, can create a devascularized wound bed and skull base defect that is difficult to repair. Noncurative treatments that leave persistent tumor also may compromise CSF leak repair.

Conversely, tumors can lead indirectly to CSF leaks by obstructing CSF flow, resulting in hydrocephalus. Success in these cases usually requires

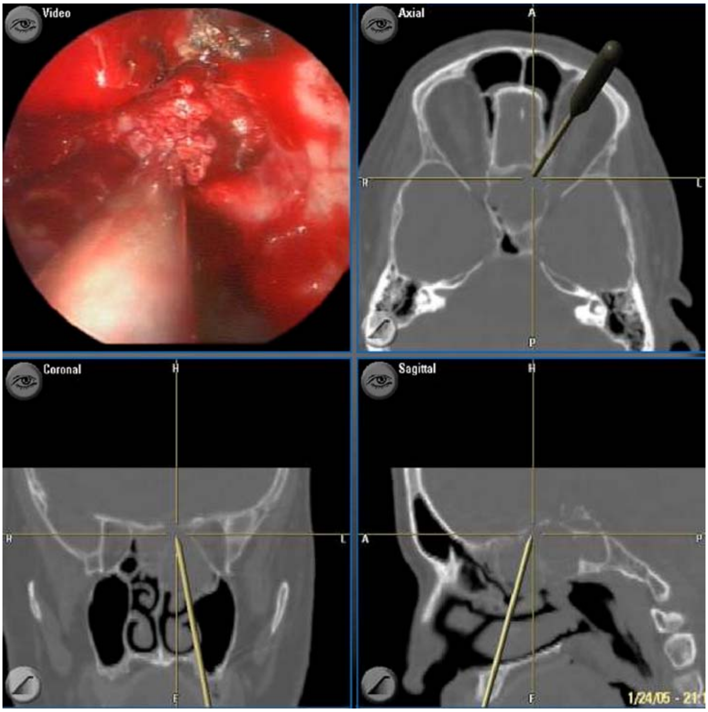

Fig. 3. Endoscopic resection of this large meningioma (triplanar imaging) resulted in a 2 × 3 cm skull base defect that was repaired endoscopically using soft tissue underlay and overlay grafts without the use of a lumbar drain.

treatment of the primary tumor to correct the obstruction or long-term shunting to divert the elevated CSF pressure. Repairing the CSF leak without treating the obstructing lesion may worsen the high-pressure condition because the internal relief valve for the patient's intracranial hypertension is removed.

Congenital

Congenital CSF leaks and encephaloceles are challenging to treat and are relatively rare. Our series showed that approximately 50% of congenital defects originate at the foramen cecum, and the other half occur in the vicinity of the cribriform plate or ethmoid roof [7]. These deformities typically are characterized by a funnel-shaped defect of the bony skull base through which a meningoencephalocele herniates into the sinonasal cavity. Surgical placement of epidural grafts can be difficult because of this misshapen, funnel-shaped skull base. Improved instrumentation has enabled repair of congenital encephaloceles at age 23 months [8]. ICPs in this group are generally normal, with the rare exception of patients with congenital hydrocephalus.

Similar to patients with hydrocephalus secondary to an obstructing tumor, the underlying high-pressure condition should be treated before definitive repair of the skull base defect.

Spontaneous

The authors' definition of spontaneous CSF leaks is limited to patients with no other discernible etiology for the CSF leak. Historically, a variety of clinical conditions have been classified as "spontaneous" CSF leaks, including leaks associated with tumor, delayed traumatic leaks, and leaks associated with congenital skull base malformation [9,10]. We believe CSF leaks that arise secondary to another condition (eg, tumor, trauma, congenital malformation) should be classified and described as such, even if the temporal history of leak occurrence is "spontaneous."

Clinical, radiographic, and demographic data suggest that spontaneous CSF leak patients represent a distinct clinical entity that is likely a variant of benign intracranial hypertension, and their elevated CSF pressures contribute to the development of CSF leaks [11]. Patients are most commonly middle-aged, obese women with pressure-type headaches, pulsatile tinnitus, and balance abnormalities in addition to their CSF rhinorrhea. Radiographically, they often have empty, expanded sellae, broadly attenuated skull bases, arachnoid pits, and multiple skull base defects secondary to chronic hydrostatic forces [12]. ICPs in these patients can be measured reliably via lumbar puncture or by using an indwelling lumbar drain and typically range from 15 to 52 cm H_2O [13]. Using the modified Dandy criteria and evaluating clinical, radiographic, and ICP data for the most rigid diagnosis of benign intracranial hypertension have shown that more than 70% of spontaneous leak patients meet the diagnostic criteria for benign intracranial hypertension (unpublished data). Of all etiologies for CSF leaks, the spontaneous group is associated with the highest rate (50–100%) of encephalocele formation, and there are often large meningoencephaloceles herniating through relatively small bony defects. Spontaneous leaks have the highest recurrence rate after surgical repair of the leak (25–87%) compared with less than 10% for most other etiologies [9,10,14]. Unfavorable conditions, such as elevated ICP, associated meningoencephaloceles, and broadly attenuated bony skull base undoubtedly contribute to this higher failure rate.

Preoperative issues

To achieve a successful repair, preoperative studies must confirm the diagnosis and localize the site of the CSF leak. β_2-Transferrin is a protein present only in CSF, perilymph, and aqueous humor. Only 0.17 mL of nasal fluid is needed for testing using newer laboratory techniques [15], but this may be difficult to obtain in cases of intermittent leaks. False-positive and false-negative results are unlikely with β_2-transferrin testing, but can occur

[16]. β_2-Transferrin provides an accurate, noninvasive method to establish the diagnosis of an active CSF leak, but it provides little information on the precise location of the leak. Beta trace protein is another noninvasive marker that is specific for CSF and is used most commonly in Europe [17].

Preoperative imaging for endoscopic CSF leak repairs always requires coronal and, in some cases, axial CT scans to define the bony anatomy. If the diagnosis is in doubt or the patient is unable to collect fluid for β_2-transferrin, a CT cisternogram may be performed at the same time, but this requires a lumbar puncture. MRI may be useful, particularly in cases in which neoplasms or other intracranial pathology are present, but is not required in all cases [18,19]. Radioactive cisternograms are used less commonly today because they are less accurate in making a definitive diagnosis and localizing the site of the leak. Radioactive cisternograms may improve diagnostic sensitivity in cases of low volume or intermittent leaks because the pledgets remain in place for several hours.

Preoperative intrathecal fluorescein (as described subsequently in the surgical technique section) with a thorough endoscopic examination is useful in establishing the diagnosis of CSF leak, but its ability to localize the leak site precisely may be limited. If a patient has not had prior sinus surgery, skull base exposure is limited. If extensive sinus surgery was performed previously with adequate exposure of the skull base, it may be helpful and accurate. Most estimates place the accuracy around 96%, but there still can be false-positive and false-negative results. Intraoperatively, when wide surgical exposure is obtained, intrathecal fluorescein is useful in localizing the defect and ensuring a watertight closure. Depending on the rate of the leak, the rate of CSF turnover, and the timing of the intrathecal injection, the fluorescein may be significantly diluted or excreted by the time of surgery. Use of a blue light filter can improve the detection of dilute fluorescein.

Deciding which preoperative test is needed for a given patient should be based on the clinical picture and the precise information needed. The invasiveness of the diagnostic test and the risks to the patient also should be taken into account.

Intraoperative concerns

Lumbar drain and intrathecal fluorescein

In appropriate cases, a lumbar drain is placed before beginning the surgical approach. Patients with high-volume CSF leaks can have a relative depletion of CSF, and it can be difficult to identify the subarachnoid space and withdraw CSF or place the lumbar drain. In these cases, it may be easiest to place the lumbar drain with the patient awake and in a sitting position to fill the lumbar cistern with CSF. The other option is to place the lumbar drain after intubation and elevate the head of the bed to assist in dilating the lumbar cistern with CSF.

Fluorescein (0.1 mL of 10% solution diluted in 10 mL of CSF) is injected slowly into the intrathecal space through the spinal needle over 10 minutes. Fluorescein can aid in precise identification of the bony skull base defect and associated CSF leak. The authors have not noted any complications from fluorescein, when used as described. Complications usually are related to higher concentrations, more rapid injections, or suboccipital punctures [20]. After fluorescein instillation is complete, the lumbar catheter is inserted, secured, and clamped for the initial portion of the case. It may be difficult to inject fluorescein through the lumbar catheter; the authors prefer to inject it through the spinal needle before catheter insertion. Later in the surgical case, after the skull base defect is exposed, and preparations for graft placement are being made, 10 to 15 mL of CSF is removed over 15 minutes to aid in reduction of the cauterized encephalocele base. After graft placement, the lumbar drain is kept open and draining 5 to 10 mL per hour for the remainder of the procedure and for the initial postoperative period. Diligent care of the lumbar drain is required during the immediate postoperative period. The temptation to clamp the drain during patient extubation or transport should be resisted; this is precisely when the greatest risk exists for ICP elevation owing to coughing, Valsalva maneuvers, and patient movement that would be transmitted against the graft. The height of the drain is adjusted to keep the drainage between 5 and 10 mL of CSF per hour.

The lumbar drain is most important during the first 24 hours after surgery. During this period, it is especially useful in avoiding large spikes in ICP if the patient coughs or strains during extubation or transport or has nausea and vomiting during the immediate postoperative period. Keeping the drain in longer than 24 to 48 hours probably does not provide any significant advantage to the repair. The tensile strength of the repair probably increases little during the first week. Most of the structural support of the repair rests on any underlay graft placed in the epidural space and on intranasal packing compressing the extracranial fascia or mucosa graft against the recipient bed. For most repairs, the authors clamp the lumbar drain for 6 to 12 hours to ensure leak cessation, then remove it on postoperative day 1 or 2. If the patient leaks, the lumbar drain can be reopened for 2 to 3 days or returned to the operating room for surgical exploration.

Positive-pressure ventilation

Positive-pressure ventilation in patients with a CSF leak carries the risk of pneumocephalus. Fatal cases have been reported from patients blowing their nose [21] or after pneumotoscopy [22] in the presence of patent cranial fistulas. To decrease this risk, the anesthesiologist can perform rapid-sequence intubation and minimize masking the patient and using positive-pressure ventilation.

Antibiotics

The authors do not use long-term prophylactic antibiotics in patients recently diagnosed with CSF leaks, but do use perioperative antibiotics. During surgery, tissue grafts are placed through the contaminated or colonized nasal cavity to rest against brain tissue at the skull base defect and risk a central nervous system infection. The authors generally use intravenous ceftriaxone because of its CSF penetration. Trimethoprim/sulfamethoxazole and levofloxacin are other alternatives that afford a degree of blood-brain barrier penetration and can be helpful in patients with cephalosporin allergies. Additionally, the authors irrigate the sinonasal cavity with clindamycin solution during the procedure in an attempt to minimize bacterial contamination and seeding of graft material.

Surgical approach

The exact surgical approach used for CSF leak repair depends on proper identification of the site of the skull base defect. At times, the site of the leak may be obvious from the patient's history and imaging studies, but in many cases, the use of intrathecal fluorescein, as described earlier, is extremely useful.

Ethmoid roof, cribriform, central sphenoid, and perisellar regions

Generally, leaks in the cribriform plate and ethmoid roof are treated with a standard transnasal endoscopic approach. After decongestion with topical and injected vasoconstrictors, the nose is irrigated with clindamycin to decrease bacteria within the surgical field and reduce the potential for intracranial seeding. A complete endoscopic ethmoidectomy and maxillary antrostomy usually are needed to provide adequate exposure of the skull base defect and leak. Frontal sinusotomies, sphenoidotomies, and middle/superior turbinectomies are performed if additional exposure is needed. Sinuses adjacent to the CSF leak site may need to be opened to prevent postoperative obstruction secondary to scarring or packing. Frontal sinusotomies and sphenoidotomies often are required even though the leak may be in the ethmoid roof or cribriform. These procedures proactively prevent the formation of iatrogenic mucoceles in the surrounding sinuses and minimize "collateral damage."

Defects in the central sphenoid can be approached through the endoscopic transethmoid or direct parasagittal approaches and a wide sphenoidotomy. Alternatively, the posterior nasal septum and intersinus septum can be resected for additional exposure of the midline perisellar or clival regions. Defects located in the lateral recess of the sphenoid sinus are difficult to access by the midline transeptal or transethmoid approaches and may require an endoscopic transpterygoid approach [23]. After a total ethmoidectomy, wide sphenoidotomy and wide maxillary antrostomy are performed, the posterior wall of the maxillary sinus is removed, and the pterygopalatine fossa is entered. The internal maxillary artery and its branches are identified, moved inferiorly, or clipped and divided to expose the deeper areas of the pterygopalatine fossa. Cranial nerve V2, the vidian nerve, and the sphenopalatine ganglion are dissected free and preserved if possible. The anterior wall of the sphenoid sinus that has pneumatized the pterygoid plates is drilled or curetted away to gain access to the lateral recess of the sphenoid sinus.

Frontal sinus

Frontal sinus CSF leaks generally can be divided into three anatomic sites: (1) immediately adjacent to the frontal recess, (2) direct frontal recess involvement, and (3) located within the frontal sinus proper. Although most leaks are limited to one of these distinct sites, some defects encompass multiple anatomic areas. This anatomic classification of skull base defect sites is clinically relevant because it often determines the surgical approach needed for repair [24].

Skull base defects located in the anterior-most portion of the ethmoid roof just posterior to the frontal recess do not involve the frontal sinus or its outflow tract directly because of their proximity; the frontal recess must be opened surgically to avoid iatrogenic mucoceles. Defects that directly involve the frontal recess may require a combined above-and-below approach using endoscopic and open techniques because the superior extent of the defect may be difficult to reach endoscopically, and the inferior/posterior extension of the defect may be difficult to reach from an external approach. The final anatomic site for frontal sinus CSF leaks is within the frontal sinus proper involving the posterior table above the isthmus of the frontal recess. Endoscopic approaches continue to expand with improved equipment and experience; however, defects located superiorly or laterally within the frontal sinus still may require an osteoplastic flap with or without obliteration. Frontal trephination and an endoscopic modified Lothrop procedure are adjuvant techniques that can be useful for unique cases of leaks that are located in the frontal sinus proper or possibly with extension into the frontal recess itself. The specific approach depends on the site and size of the defect, the equipment available, and surgical experience.

Intracranial approach

Otorhinolaryngologists now are able to access all areas of the anterior and central skull base successfully, but there are still limitations to extracranial approaches. These may include multiple, comminuted defects, broadly attenuated or badly deformed skull bases, tumors with intracranial extension that are not amenable to endoscopic resection, large bilateral defects in an anosmic patient, and high-pressure leaks requiring CSF diversion procedures.

Preparation of recipient bed

When the skull base defect is localized, and adequate exposure has been obtained via an appropriate surgical approach, the recipient bed is prepared by removing several millimeters of mucosa surrounding the bony defect. Sinus mucosa continues to secrete mucus and may separate the graft from the recipient bed if it is not removed; it is crucial to remove the mucosa thoroughly to expose the underlying bone. The authors do not attempt to remove 100% of the mucosa within a given sinus, unless a defect located in the periphery of the frontal sinus is being treated, and it is planned to obliterate the frontal sinus. This approach is particularly applicable for sphenoid leaks, for which it is virtually impossible to remove all mucosa from the lateral aspects of the sphenoid. When appropriate mucosa is removed, a diamond burr or curette can be used to abrade the recipient bed bone lightly and stimulate osteoneogenesis.

When the borders of the bony skull base defect are prepared, any encephaloceles are reduced using bipolar cautery as much as possible. Malleable suction monopolar cautery devices can be used selectively within the ethmoid cavity and are particularly useful for reaching difficult areas in the anterior and lateral skull base. Monopolar cautery is avoided near or adjacent to the lamina papyracea, optic nerve, or carotid arteries.

As the encephalocele is progressively ablated, meticulous hemostasis is required. Hemostasis is especially important when treating the encephalocele base to avoid the potentially devastating complication of intracranial hemorrhage. This complication could occur if the encephalocele was sharply resected or avulsed and the base retracted intracranially. Precise application of electrocautery to the stalk or base helps prevent intracranial bleeding. When the encephalocele base is reduced, if a lumbar drain has been placed preoperatively, the drain is opened, and CSF is diverted away from the graft site and into the collection bag. Removing approximately 10 to 15 mL and positioning the collection bag to establish a flow rate of 5 to 10 mL/h allows the encephalocele base to be reduced intracranially, facilitating intracranial graft placement.

Skull base reconstruction

When an appropriate surgical approach with adequate exposure has been performed, and the recipient bed is prepared with ablation of any encephaloceles that may be present, skull base reconstruction is undertaken. The decision of how to reconstruct the skull base depends on the cause of the leak, the size of the resultant bony defect, and the underlying ICP [25]. Small defects of 2 to 3 mm or simple cracks in the skull base make it difficult to place an underlay graft within the epidural space, and in these cases, a simple soft tissue overlay graft suffices. Defects of moderate size ($\geq$4 mm) and with normal underlying ICPs, such as after a tumor resection, can be reconstructed successfully in a multilayer fashion, using soft tissue for underlay and overlay grafts. Extremely large defects or smaller defects with elevated ICPs, such as spontaneous CSF leaks or leaks with hydrocephalus, probably benefit from a rigid underlay graft to provide structural support followed by a soft tissue overlay graft.

For underlay grafts, the repair is performed by gently elevating the dura above the bony skull base defect and placing grafts in the epidural space. An otologic elevator is helpful in dissecting the dura and defining the epidural space. When bone grafts are used, care in graft design and placement is needed. In some patients, such as patients with spontaneous leaks, the entire skull base is attenuated and can fracture easily, creating an even larger defect. These defects often have complex three-dimensional configurations, requiring precise shaping of the bone graft. Donor options are septal or mastoid bone. When the bone graft is of satisfactory size and shape, it is soaked in clindamycin solution to decrease the risk of intracranial seeding of bacteria. The graft is placed carefully in the epidural space to close the bony defect. We generally do not use cartilage grafts because of their increased thickness, tendency to fracture, and lower structural strength compared with bone grafts. When using soft tissue underlay grafts, the technique is identical. Although a variety of rigid and soft tissue grafts have been used successfully, it is imperative not to place mucosal grafts in an underlay fashion. Doing so may result in mucoceles, meningitis, or other central nervous system complications (Fig. 4).

After positioning an appropriate underlay graft (if needed), an overlay graft is placed over the entire repair. Care must be taken not to obstruct surrounding sinuses, leading to iatrogenic mucoceles. Multiple layers of absorbable packing follow the overlay graft. In certain locations, such as the sella or sphenoid sinus, abdominal fat may be used to augment or replace absorbable packing. In these cases, the fat serves as biologic packing and

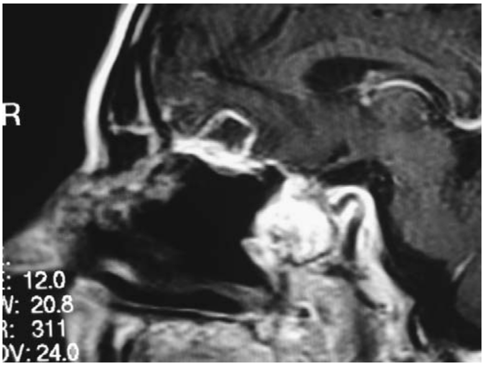

Fig. 4. Iatrogenic CSF leak that occurred during functional endoscopic sinus surgery was repaired using a middle turbinate graft (elsewhere). This patient had a seizure, and subsequent endoscopic re-exploration showed the mucosal covered graft approximately 2 cm intracranially. Note ring-enhancing lesion on sagittal T1-weighted MRI.

is not intended to obliterate the sphenoid completely, but rather to serve as temporary support with the goal of maintaining long-term patency of the sinus. In contrast to frontal sinus obliterations in which complete mucosal removal is possible via an osteoplastic approach, it is virtually impossible to remove all mucosa completely from the sphenoid.

Graft materials

Multiple varieties of grafting materials and placement techniques have been described, and most have been successful. The specific graft material chosen depends on the size and location of defect, the anatomic character of the defect and recipient bed, and the presence of elevated CSF pressure. Each skull base defect, meningoencephalocele, and leak is unique; an algorithmic approach is not optimal. Experimental evidence shows that a free graft guides wound healing by acting as a scaffold [26]. Free grafts are adherent to bone at 1 week and replaced by fibrous connective tissue at 3 weeks with some degree of postoperative contracture. We generally recommend a multilayer closure, when possible, that includes an underlay graft placed in the epidural space followed by an overlay graft placed intranasally against exposed bone around the defect. This type of repair provides structural support from the underlay graft in the epidural space and watertight closure from the overlay graft.

Soft tissue grafts can be autologous temporalis fascia, alloplastic collagen materials (eg, Duragen), cadaveric fascia, pericardium, or dermis. All of these materials have the advantage of being readily available and acceptable for either underlay or overlay grafts. None has shown superior efficacy, and choice depends on the surgeon's preference. Alternatively, numerous authors use free mucosal grafts for soft tissue reconstruction. Septal and inferior turbinate mucosae are relatively thick and provide sufficient graft material for most repairs. Middle turbinate mucosa also is an option, but it tends to be thinner, and there is less material available. Composite grafts using turbinate bone and mucosa provide a two-layer closure, but both layers are placed simultaneously in an overlay fashion and do not have the stability of an epidural graft. In addition, it is difficult to sculpt the bony portion of a composite graft to fit the skull base defect precisely while it is still attached to its mucosal covering. As previously mentioned, the reader is cautioned that mucosal soft tissue grafts must be placed so that the mucosal surface is oriented into the sinonasal cavity. Placement of mucosa in the epidural space or reversing its orientation can lead to intracranial mucoceles, meningitis, or other central nervous system complications.

Tissue adhesives

A variety of tissue adhesives have been reported anecdotally for CSF leak repairs, but no scientific clinical studies have been conducted. One experimental study using a mouse model showed an apparent advantage to using fibrin sealant with a free muscle graft [27]. If tissue adhesives are used, they must be applied conservatively because a thick layer of adhesive may prevent the graft material from coming into contact with the wound bed.

Packing

Degradable packing materials, such as Gelfoam, Surgicel, and Avitene, have been used with success. There is no proven scientific advantage to any one product. Gelfilm or Silastic sheeting used between multiple layers of packing may prevent the inadvertent removal or movement of all the layers of packing and possible disruption of the graft during the early postoperative period.

Postoperative issues

Activity

All patients are kept at strict bed rest while lumbar drains are in place. After the lumbar drain is removed, patients gradually resume ambulation. Patients are instructed on movement techniques to avoid breath holding and Valsalva maneuvers and are encouraged to inhale or exhale continuously when changing position. The authors encourage light activity for 6 weeks after surgery.

Bed position and lumbar drain management

Alterations in bed position alter the CSF pressure at the graft site. When the patient is lying perfectly flat, the ICP is roughly equivalent at all points from the lumbar cistern to the skull base. As the head of bed is raised, CSF pressure at the anterior skull base decreases, while the pressure in the lumbar cistern increases proportionally. Brain parenchyma also may help to maintain the position of epidural grafts when the patient is raised to the sitting position. The authors keep patients slightly elevated at 15° while the lumbar drain is in place. In patients with suspected ICP elevation, additional clinical information that may be important for future management decisions can be obtained by measuring ICPs through the lumbar drain as described elsewhere [13]. When the drain is removed, the authors allow approximately 4 hours for the lumbar drain catheter site to seal. Thereafter, the authors gradually elevate the head of the bed to 30° to decrease the CSF pressure at the skull base defect repair site. If patients do well and do not exhibit any signs of a spinal headache, they can be advanced to a sitting position and light activity.

Acetazolamide

Acetazolamide (Diamox) is a diuretic that can decrease CSF production 48% [28]. The authors have begun to use it in cases in which elevated ICP plays a role. Acetazolamide has reduced ICP in several spontaneous leak patients and improved their symptoms of pulsatile tinnitus and pressure-type headaches. The optimal timing, dosing, and long-term benefits of this approach have not been proven, but it may reduce the risk of developing subsequent skull base defects in patients with elevated CSF pressures. The authors periodically monitor electrolytes in any patient placed on long-term diuretic therapy.

Endoscopic care

Patients are seen every 1 to 2 weeks postoperatively. Conservative endoscopic débridement is performed to maintain patency of the dependent sinuses surrounding the repair to avoid stasis of secretions and bacterial infections. The area of the packing and graft specifically are avoided to allow adequate healing. By 6 weeks postoperatively, most patients have returned to relatively normal activity levels, and little packing remains.

Continuous positive airway pressure

The authors have repaired several patients with obstructive sleep apnea who use continuous positive airway pressure. The authors restrict the use of continuous positive airway pressure during the immediate postoperative period, to avoid the risk of pneumocephalus from positive-pressure ventilation. All of the authors' patients have been able to resume using continuous positive airway pressure safely 4 to 6 weeks after surgery.

Summary

The role of the otolaryngologist in diagnosing and treating CSF leaks of the anterior and central skull base continues to expand. A comprehensive understanding of the physiology, pathology, diagnosis, and treatment approaches is crucial to treat this wide variety of skull base defects properly.

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