The Management of Cerebrospinal Fluid Leaks in Patients at Risk for High-Pressure Hydrocephalus

Ricardo L. Carrau, MD; Carl H. Snyderman, MD; Amin B. Kassam, MD

Objectives/Hypothesis: The transnasal endoscopic approach has become the preferred technique for the surgical management of patients with cerebrospinal fluid (CSF) leaks of the anterior, sellar, and parasellar skull base. The literature has reported an 85% to 100% success rate for the endoscopic repair of CSF leaks, which compares favorably with that reported after transcranial repair. Despite an adequate repair, a subpopulation of patients remain at high risk for recurrence of the CSF leak attributable to undiagnosed high-pressure hydrocephalus. Patients at high risk for high-pressure hydrocephalus include those who have had a subarachnoid hemorrhage as a result of trauma (accidental or surgical) or stroke and those with spontaneous CSF leaks. Study Design: With the goal of reducing the risk of recurrence, the authors developed a protocol for the identification and management of patients with CSF leaks who are at risk for high-pressure hydrocephalus. Methods: The protocol includes endoscopic repair, temporary CSF diversion, measurement of CSF pressure after the repair, and immediate ventriculoperitoneal shunting if necessary. Results: During the period of September 1999 to April 2002, the authors repaired 25 CSF leaks through an endonasal endoscopic approach. Nineteen patients were considered at high risk for high-pressure hydrocephalus. Using the protocol described, the authors identified six patients (31%) with CSF leaks that could be associated with undiagnosed high-pressure hydrocephalus. All CSF leaks were successfully repaired using a transnasal endoscopic repair. Six patients with high-pressure hydrocephalus underwent ventriculoperitoneal shunting after repair of the CSF leak. No recurrence has been observed at a follow-up ranging from 24 to 84 months (median period, 30 mo). Conclusion: Patients with high-pressure hydrocephalus may be identified in a prospective fashion to prevent recurrence or persistence of the CSF leaks. The presence or absence of high-pressure CSF may be established by means of direct CSF pressure measurement through lumbar puncture postoperatively. This allows early intervention and prevention of recurrence. Key Words: Cerebrospinal fluid, endoscopic sinus surgery, paranasal sinuses, hydrocephalus.

Laryngoscope, 115:205–212, 2005

INTRODUCTION

A cerebrospinal fluid (CSF) leak and consequent rhinorrhea implies a communication between the subarachnoid space and the sinonasal tract. Patients with CSF leaks present with a variety of symptoms such as clear nasal discharge and headache or complications such as pneumocephalus, meningitis, or brain abscess. Prompt identification and closure of the CSF fistula is critical to avoid development of or progression to these life-threatening complications.1,2

Most CSF leaks are caused by traumatic fractures of the cranial base or by iatrogenic injuries secondary to endoscopic sinus surgery and/or cranial base surgery. Cerebrospinal fluid leaks are diagnosed in 3% of patients with closed head injuries and in as many as 30% of patients with a fracture of the skull base.3 Similarly, iatrogenic trauma, such as traditional cranial base surgery and endoscopic sinus surgery, is associated with CSF leaks. Although less than 1% of patients who undergo endoscopic sinus surgery develop a CSF fistula, endoscopic sinus surgery is one of the most common causes of CSF leaks in our practice and other practices.4–22 Nontraumatic CSF leaks may also occur secondary to tumors of the skull base or high-pressure hydrocephalus (HPH), or both. The causes or origins of HPH include tumors, trauma, infections, and hemorrhagic cerebrovascular accidents. Occa-
sionally, no cause or origin is identified for the HPH; therefore, it is deemed “idiopathic.”

**Diagnosis**

The diagnosis and management of a CSF leak involves three critical steps: distinguishing a CSF leak from other sources of rhinorrhea, locating the fistula, and ruling out high intracranial pressure secondary to altered CSF dynamics. A clinical diagnosis of a CSF leak is based on a history of clear, watery nasal drainage, usually unilateral, commonly associated with headache. A history of tumor, trauma, or previous surgery involving the paranasal sinuses or cranial base heightens the level of suspicion. Increased rhinorrhea when the patient leans over, tilts the head forward, or performs a Valsalva maneuver further suggests the presence of a CSF leak. Occasionally, a patient presents not with rhinorrhea, but with mental changes or other neurological deficits caused by a life-threatening complication arising from the CSF leak, such as pneumocephalus, brain abscess, or ascending bacterial meningitis.

**Laboratory Tests**

It should be remembered that other conditions such as vasomotor rhinitis and sympathetic denervation can cause profuse rhinorrhea that may be confused with a CSF leak. Nasal irrigation with saline solution during endoscopic sinus surgery may accumulate in the paranasal sinuses and later present as postoperative rhinorrhea. Thus, biochemical testing is indicated to confirm the true nature of the nasal drainage. Cerebrospinal fluid will be high in glucose and low in protein. However, normal nasal discharge has been shown to be falsely positive for glucose in 45% to 75% of cases. Beta-2 transferrin is a protein found in CSF, aqueous humor, and perilymph but not in blood or nasal secretions. Detection of beta-2 transferrin, based on standard, reproducible principles of protein electrophoresis and immunofixation, is a noninvasive, reliable chemical marker of CSF leakage.

**Identifying Site of Lesion**

When a CSF leak develops after sinus surgery, the endoscopic surgeon typically has an impression as to the possible site of injury to the cranial base (i.e., site of the CSF fistula). Therefore, a thorough endoscopic office examination of the nasal cavity may reveal the site of the leakage. However, the fistula is difficult to identify in patients with low-pressure leaks, especially in the presence of postoperative tissue edema and blood clots.

Intrathecal injection of contrast materials and radioactive tracers has been used to confirm a CSF leak and to identify the site of origin. Intrathecal fluorescein may be used to aid in the diagnosis and localization of the CSF leak. During this test, 5 mL fluorescein at a concentration not greater than 5% is diluted with 10 mL CSF (obtained through a lumbar puncture) and is then injected intrathecally. Fluorescein is neurotoxic, and a low concentration—low volume injection is critical to avoid the neurological complications associated with higher concentrations. After intrathecal injection of the fluorescein solution, the CSF leak may be visualized using the nasal endoscope. Under the Wood lamp (i.e., black light), fluorescein appears as bright yellow-green; nonetheless, the yellowish color of fluorescein may be identified without the need for special lighting.

Despite its extensive use in Europe, intrathecal fluorescein is not universally accepted in the United States as a diagnostic tool. This is partly attributable to the logistics of performing a lumbar puncture in an outpatient setting and to medicolegal considerations (the fluorescein drug package insert includes an advisory warning against intrathecal use). In addition, intrathecal injections are rarely critical to the proper identification of the CSF fistula. Exceptional patients are those with multiple fistulas and patients who have had repeated episodes of meningitis in the absence of an apparent cranial base defect or other predisposing factors such as rhinosinusitis or otitis media.

Other authors have advocated the intrathecal injection of air, which can “bubble” out at the fistula site, thus aiding in its identification. However, air is an irritant to the brain and may induce seizures. Normal saline solution may be injected into the intrathecal space to increase the pressure within the subarachnoid space and thus aid in the identification of the leak.

Scintigraphy has been advocated for the identification of a CSF leak. Indium (In 111) is the most frequently used radioisotope. Although radioisotope tracing is a sensitive test, it is associated with a high false-positive rate. In addition, radionuclide studies have a poor resolution that precludes establishing the specific point of leakage. Thus, we do not advocate scintigraphy. The presence of the CSF leak is ascertained with a noninvasive test, beta-2 transferrin electrophoresis, and its site of origin is better identified by other types of imaging or endoscopy, or both.

An important consideration in a patient presenting with spontaneous rhinorrhea or rhinorrhea after skull base trauma is to distinguish whether the CSF rhinorrhea arises from the sinonasal tract or from other sites, such as the middle ear or mastoid. A CSF fistula within the temporal bone may drain into the nose through the eustachian tube, leading to an incorrect diagnosis. Imaging is of utmost importance to locate the site of the fistula.

Radiographically, a high-resolution computed tomography (HRCT) scan performed in axial and coronal planes using 3-mm fine cuts can be used to identify a cranial base defect. High-resolution computed tomography is our preferred initial imaging study to aid in the identification of the site of injury and its extent. High-resolution computed tomography with contrast also provides information about the possibility of intracranial complications such as hematoma or brain contusion that occur in the setting of acute trauma (iatrogenic or other). High-resolution computed tomography with views taken at a perpendicular plane from the suspected site of injury can better evaluate the integrity of the bony wall in question. Therefore, coronal computed tomography (CT) views are best to evaluate defects of the cribriform plate, fovea ethmoidalis, or plenum sphenoidale, whereas axial views are superior to evaluate the posterior wall of the frontal or sphenoid sinuses. Magnetic resonance imaging (MRI) is recommended to assess the contents of a herniation of the me-
ninges and/or brain herniation through the cranial base defect (i.e., meningocele or encephalocele). We have encountered an anterior cerebral artery within a meningoencephalocele herniated into the nasal cavity. Even HRCT may not identify small areas of surgical trauma or linear nondisplaced fractures. In this case, HRCT can be used in conjunction with intrathecal contrast to identify the fistula. Metrizamide CT cisternography has been documented to be both sensitive and reliable. Newer, less toxic, water-soluble nonionic contrast materials have replaced metrizamide and result in fewer side effects (i.e., headache, nausea, and arachnoiditis). However, contrast studies require the presence of an active fistula. Intermittent leaks that are temporarily sealed by swelling, inflammation, or brain herniation may yield a false-negative result. A saline challenge test, which involves the intrathecal injection of saline solution to increase the CSF pressure, enhances the sensitivity of the test to diagnose the presence of a fistula.

Magnetic resonance imaging cisternography may complement the information offered by HRCT without the use of intrathecal contrast. Magnetic resonance imaging cisternography has been effective in identifying CSF leaks in patients with normal findings on HRCT. However, we have had mixed results with the use of this technique.

**Historical Background**

In a comprehensive review of 53 CSF leaks that were repaired through an endonasal endoscopic approach, we reported three patients in whom CSF leaks persisted or recurred, requiring additional surgery. These three patients were subsequently diagnosed with HPH. In each case, the CSF leak was repaired endoscopically. Patients with elevated CSF pressure underwent ventriculoperitoneal (VP) shunting. Subsequent to the present report, we initiated a protocol to prospectively identify and treat patients with CSF leaks who are at risk for HPH and therefore at risk for recurrence of the CSF leak.

**PATIENTS AND METHODS**

All patients presenting to the Center for Cranial Base Surgery, University of Pittsburgh Medical Center with CSF fistulas between September 1999 and April 2002 were included in the study. All CSF leaks were verified with β-2 transferrin. The site of the leak was identified using a combination of tests including nasal endoscopy, HRCT scan, and MRI or CT cisternography. All patients underwent an endonasal endoscopic repair.

Patients with recurrent CSF leaks, a history of head and/or cranial base trauma, or a history of cranial base surgery and those with “spontaneous” CSF leaks were considered at high risk for HPH. Patients at risk for HPH were treated according to the following protocol (Fig. 1).

The CSF leak was repaired through an endonasal endoscopic approach following sound surgical principles including adequate exposure, hemostasis, preparation of the fistula, and stable grafting. A lumbar spinal drain was placed intraoperatively or immediately after the surgery. Three to five days after surgery, the lumbar spinal drain was clamped. If no CSF leak was identified for 24 hours, the lumbar drain was removed. Twenty-four hours later, a lumbar puncture was performed to measure the CSF opening pressure. If the CSF opening pressure was elevated, a VP shunt was recommended; if the CSF opening pressure was normal, the patient was discharged home and followed in our outpatient offices.

As an alternative, patients with CSF leaks isolated to the sphenoid sinus were treated with obliteration of the sinus using abdominal fat followed by stabilization with a nasal packing. A postoperative lumbar spinal drain was not inserted. A lumbar puncture was performed 3 to 5 days after surgery to measure the opening pressure. As previously mentioned, the need for a VP shunt was established if the CSF opening pressure was elevated.

A CT scan of the brain was performed 6 weeks after the surgical closure in patients with normal CSF opening pressure. Ventriloculomegaly of the temporal horns and trans-ependymal edema would identify patients with HPH who may have escaped identification (false-negative test results). Cerebrospinal fluid leaks in patients who did not present with any of the previously mentioned high-risk factors were repaired endoscopically, and a spinal drain was not used.

**RESULTS**

In all, 25 patients were treated during the period of the present study (Table I). The study group was composed of 14 female and 11 male patients with a median age of 41 years (age range, 8–66 y). Various causes or origins were identified for the CSF leak, including “trauma” (n = 4), endoscopic surgery (n = 5), anterior cranial base surgery (n = 3), sellar surgery (n = 4), or “spontaneous” origin (n = 9).

Nineteen patients, including those who developed a CSF leak following trauma or trans-sellar or cranial base surgery and those with “spontaneous” leaks, were deemed at high risk for HPH. Five of nine patients (55%) with...
“spontaneous” leaks were found to have HPH. One of four patients (25%) with a CSF leak after cranial base surgery showed evidence of HPH. None of the three patients with CSF leaks associated with a history of a closed or penetrating head injury showed HPH. Likewise, none of three patients with CSF leaks presenting after surgery for pituitary tumors was found to have HPH (one of the four patients who underwent “sellar surgery” was deemed at low risk because a cyst, not a neoplasm was found). Thus, during the study period, 6 of 19 (31%) “high-risk” patients were identified to have HPH and underwent VP shunting. All patients had successful repair endoscopically. Revision surgery was not required. No patient has developed a recurrence of the CSF leak at a median follow-up period of 30 months (range, 24–84 mo). Patient 14 had the only surgical complication. This patient developed a small venous infarction of the temporal lobe after the placement of a VP shunt. This complication probably arose from shifts in the brain parenchyma caused by the ventricular contraction and expansion. She developed a mild dysphasia that resolved completely within 4 weeks.

DISCUSSION

Literature Review

A variety of techniques has been reported for the repair of a CSF fistula. In 1952, Hirsch32 described the first endonasal repair of CSF rhinorrhea using a septal flap. Subsequently, Montgomery33 described his experience with septal flaps through an external nasal approach to treat CSF rhinorrhea. In 1976, McCabe34 reported his experience with the use of osteomucoperiosteal flaps from the septum or middle turbinate through an external ethmoidectomy approach. In 1989, a report by Yessenow and McCabe35 updating McCabe’s experience reported a 100% closure rate with a follow-up of 1.6 to 22 years. The use of these and other local flaps to treat CSF fistulas through an endoscopic approach was subsequently reported.13,36

In 1985, Calcaterra37 described the use of free muscle or fascia grafts to treat CSF fistulas using an external ethmoidectomy approach, and in 1989, Papay et al.38 described an endoscopic technique. Multiple studies followed, reporting the use of free grafts or local flaps, or both, for the repair of CSF fistula. Amedee et al.39 reported the use of multiple free grafts, including septal mucosa, fascia, and abdominal fat, in 22 patients who underwent a transnasal microscopic approach for the repair of CSF leaks. These authors were successful in closing the CSF leaks in all but one patient (95% closure rate). The only failure occurred in a patient with a spontaneous CSF leak arising in the lateral sphenoid sinus, which was later repaired using an endoscopic technique, requiring a 70° telescope for its visualization.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (y)/Gender</th>
<th>Etiology</th>
<th>Site of Fistula</th>
<th>Hydrocephalus</th>
<th>VP Shunt</th>
<th>Follow-Up (mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>58/M</td>
<td>Surgery</td>
<td>Sphenoid</td>
<td>No</td>
<td>No</td>
<td>32</td>
</tr>
<tr>
<td>2</td>
<td>19/M</td>
<td>Surgery</td>
<td>Sphenoid</td>
<td>No</td>
<td>No</td>
<td>24</td>
</tr>
<tr>
<td>3</td>
<td>36/M</td>
<td>Surgery</td>
<td>Cribiform</td>
<td>No</td>
<td>No</td>
<td>53</td>
</tr>
<tr>
<td>4</td>
<td>61/F</td>
<td>Spontaneous</td>
<td>ESR</td>
<td>Yes</td>
<td>Yes</td>
<td>35</td>
</tr>
<tr>
<td>5</td>
<td>12/M</td>
<td>Trauma</td>
<td>ESR</td>
<td>No</td>
<td>No</td>
<td>43</td>
</tr>
<tr>
<td>6</td>
<td>27/M</td>
<td>Trauma</td>
<td>ESR</td>
<td>No</td>
<td>No</td>
<td>46</td>
</tr>
<tr>
<td>7</td>
<td>9/F</td>
<td>Surgery</td>
<td>Sphenoid</td>
<td>No</td>
<td>No</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>50/F</td>
<td>Surgery</td>
<td>Cribiform</td>
<td>No</td>
<td>No</td>
<td>39</td>
</tr>
<tr>
<td>9</td>
<td>65/M</td>
<td>Spontaneous</td>
<td>Cribiform</td>
<td>Yes</td>
<td>Yes</td>
<td>30</td>
</tr>
<tr>
<td>10</td>
<td>46/F</td>
<td>Spontaneous</td>
<td>Sphenoid</td>
<td>Yes</td>
<td>Yes</td>
<td>31</td>
</tr>
<tr>
<td>11</td>
<td>59/F</td>
<td>Spontaneous</td>
<td>Cribiform</td>
<td>No</td>
<td>No</td>
<td>27</td>
</tr>
<tr>
<td>12</td>
<td>62/M</td>
<td>Surgery</td>
<td>Cribiform</td>
<td>No</td>
<td>No</td>
<td>31</td>
</tr>
<tr>
<td>13</td>
<td>40/F</td>
<td>Spontaneous</td>
<td>Cribiform</td>
<td>No</td>
<td>No</td>
<td>25</td>
</tr>
<tr>
<td>14</td>
<td>56/F</td>
<td>Spontaneous</td>
<td>Cribiform</td>
<td>No</td>
<td>No</td>
<td>26</td>
</tr>
<tr>
<td>15</td>
<td>45/F</td>
<td>Spontaneous</td>
<td>Cribiform</td>
<td>No</td>
<td>No</td>
<td>49</td>
</tr>
<tr>
<td>16</td>
<td>23/F</td>
<td>Surgery</td>
<td>Sphenoid</td>
<td>No</td>
<td>No</td>
<td>31</td>
</tr>
<tr>
<td>17</td>
<td>48/F</td>
<td>Surgery</td>
<td>Sphenoid</td>
<td>Yes</td>
<td>Yes</td>
<td>24</td>
</tr>
<tr>
<td>18</td>
<td>29/M</td>
<td>Surgery</td>
<td>Sphenoid</td>
<td>No</td>
<td>No</td>
<td>27</td>
</tr>
<tr>
<td>19</td>
<td>54/F</td>
<td>Spontaneous</td>
<td>Cribiform</td>
<td>Yes</td>
<td>Yes</td>
<td>32</td>
</tr>
<tr>
<td>20</td>
<td>42/M</td>
<td>Surgery</td>
<td>ESR</td>
<td>No</td>
<td>No</td>
<td>25</td>
</tr>
<tr>
<td>21</td>
<td>15/M</td>
<td>Spontaneous</td>
<td>Cribiform</td>
<td>Yes</td>
<td>Yes</td>
<td>25</td>
</tr>
<tr>
<td>22</td>
<td>31/F</td>
<td>Trauma</td>
<td>ESR</td>
<td>No</td>
<td>No</td>
<td>29</td>
</tr>
<tr>
<td>23</td>
<td>66/M</td>
<td>Surgery</td>
<td>Cribiform</td>
<td>No</td>
<td>No</td>
<td>37</td>
</tr>
<tr>
<td>24</td>
<td>51/F</td>
<td>Surgery</td>
<td>ESR</td>
<td>No</td>
<td>No</td>
<td>84</td>
</tr>
<tr>
<td>25</td>
<td>56/F</td>
<td>Trauma</td>
<td>ESR</td>
<td>No</td>
<td>No</td>
<td>25</td>
</tr>
</tbody>
</table>

VP = ventriculoperitoneal; M = male; F = female; ESR = ethmoid sinus root.
Burns et al.\textsuperscript{40} and Marks\textsuperscript{41} reported the use of middle turbinates mucosa with and without free bone grafts, obtaining closure rates of 83\% (35 of 42) and 94\% (16 of 17), respectively. Similar results were obtained by Anand et al.,\textsuperscript{42} who performed repair in 11 of 12 patients presenting with CSF fistulas. Their only surgical “failure” was subsequently repaired using a transcranial approach. Lanza et al.\textsuperscript{43} repaired 42 cranial base defects in 36 patients using a mucoperichondrial or mucoperiosteal graft and septal cartilage (32 of 36) or other various techniques (4 of 36). Only two patients (6\%) had recurrence or persistence with a CSF leak (mean follow-up period of 2 years). Weber et al.\textsuperscript{44} used free grafts or vascularized flaps, or both, whether as an onlay or underlay technique, successfully repairing the CSF leaks in 42 consecutive patients. Gjuric et al.\textsuperscript{45} also used a variety of materials to endoscopically repair the defects of 30 patients with a CSF leak. Only one patient (3\%) presented with a recurrent leak requiring repair through a subfrontal approach.

Review of the reports in the literature suggest that the choice of the approach and materials used during the endoscopic endonasal closure of CSF fistulas is based on the availability of the material and on the experience and familiarity of the operating surgeon with various techniques. The use of bone or cartilage appears to be unnecessary with the possible exception of patients presenting with herniating brain or meninges. Most techniques seem to yield similar results in experienced hands. This is suggested by the results reported in the previous series and by other authors\textsuperscript{31,34-46} and has been confirmed by a meta-analysis of the literature by Hegazy et al.\textsuperscript{3} After analyzing all reports in the English literature that were made up of a series of endoscopic repairs of more than five patients, the latter authors found no significant differences in outcome, regardless of which surgical technique or which homologous material was used for the repair.

**Surgical Technique**

**Ethmoid sinus roof and cribiform plate.** If a CSF leak is suspected during endoscopic sinus surgery, the area in question should be closely examined and the overlying mucosa reflected away to determine the extent of injury. A free tissue graft may be used to patch the site of injury.

Suitable grafting materials include fascia lata, temporalis muscle, abdominal fat, septal or middle turbinate mucosa or composite grafts, periosteum, and perichondrium. If possible, the dural edges are undermined with a small elevator and the edges of the graft are tuck between the dura and the bone (i.e., inlay graft). If this is not possible because of technical difficulties or because the fistula involves a linear fracture that does not expose the dural defect, the graft is placed over the defect (outside the cranial cavity). Free muscle or fat grafts can also be used as a dumbbell-type plug. Fibrin glue may be used to increase the adhesiveness of the muscle or fascia graft. Autologous fibrin glue does not involve the infectious risks of homologous blood product transfusions. However, in most institutions autologous fibrin glue requires several hours of preparation time, which limits its usefulness in the acute care setting. Commer-

Sphenoid sinus. The sphenoid sinus can be approached trans-septally or, preferably, through a direct endoscopic approach such as the one described for pituitary surgery.\textsuperscript{47} Cerebrospinal fluid leaks involving the sphenoid sinus respond well to obliteration of the sinus. After the leak is identified, the sinus mucosa is thoroughly removed, fascia or muscle is placed against the defect, and the sinus is subsequently obliterated with abdominal free fat. The anterior wall of the sinus is then reinforced with a layer of Surgicel and Gelfilm, and the nose is packed with a \(\frac{1}{2}\)-inch strip that has been impregnated with antibiotic ointment. As an alternative, the sphenoid sinus defect can be repaired using calcium phosphate self-setting cement (hydroxyapatite cement) or an equivalent bone cement. Calcium phosphate self-setting cement can be used for direct repair of a defect, obviating the need for obliterating the sinus. However, hydroxyapatite is not well suited for high-flow leaks because the CSF can wash the cement off the defect before it sets. Furthermore, hydroxyapatite must be covered with vascularized tissue; otherwise, it can become infected with bacteria from the sinonasal tract.

An intraoperative CSF leak arising from the sella turcica during pituitary surgery most often can be repaired by obliterating the sella with free fat and reconstructing the floor of the sella with a free bone or cartilage.
graft harvested during the endoscopic approach. Thus, it does not require postoperative packing or the removal of the entire mucoperiosteum of the sinus.

Accidental injury to adjacent neurovascular structures is a consideration in patients with CSF fistula at the lateral wall of the sphenoid sinus. Adequate visualization of this area is critical. Leaks that arise in the lateral recess present technical difficulties because of their poor visualization after a traditional sphenoidotomy. Repair often requires ligation of the sphenopalatine artery and extension of the sphenoidotomy toward the pterygopalatine fossa.

**Frontal sinus.** Cerebrospinal fluid leaks involving the frontal sinus are usually repaired using a transfrontal sinus approach. The Draf approach, which involves medial widening of the frontal recesses and removal of the superior nasal septum and inferior frontal sinus septum, may provide exposure of leaks around the frontonasal recess, thus allowing an endoscopic repair.

### General Management

As previously mentioned, the general principles of management of a CSF fistula include adjunctive measures that may facilitate unhindered closure, avoiding activities that raise the intracranial pressure, such as straining, leaning forward, or lifting weights greater than 15 pounds. Other measures include bed rest, stool softeners, elevation of the head of bed, sneezing with an open mouth, and avoidance of nose blowing. "Deep extubation" to prevent straining and coughing is employed if the patient is under general anesthesia. It is important to avoid positive-pressure mask ventilation.

The use of prophylactic antibiotics for the prevention of meningitis in patients with CSF fistulas continues to be controversial. However, the use of antibiotics when the patient has an active sinus infection is warranted. In patients with indwelling lumbar catheters, prophylactic antibiotics are routinely administered and, although the concept is not universally accepted, antibiotics are thought to decrease the incidence of catheter-related infections. However, the routine use of antibiotics for traumatic CSF leaks is not of proven efficacy and may select resistant bacteria. We do favor the use of perioperative prophylactic antibiotics during the repair of the CSF leak. Antibiotics are continued until nasal packing is removed.

A postoperative CT scan without contrast within the first 24 hours after surgery is important to rule out evidence of intracranial bleeding, parenchyma injury, or tension pneumocephalus. We favor a routine CT scan of the brain, even in the absence of any neurological deficit.

Neurosurgical consultation may provide an important perspective on intraoperative and postoperative management, especially on the need for a CSF drain or a shunt. A lumbar drain is helpful to control intracranial pressure with a designated amount of CSF removed daily based on CSF production. Overdrainage should be avoided because this creates a negative intracranial pressure (i.e., suction effect) that may result in pneumocephalus and promote bacterial contamination of the CSF with resultant meningitis.

### High-Pressure Hydrocephalus

Normal intracranial pressure ranges from 5 to 15 cm of water when the patient is in supine position. However, intracranial pressure increases with positional changes, with Valsalva maneuver, and during rapid eye movement (REM) sleep. An increased intracranial pressure (i.e., HPH) is defined as sustained or intermittent pressures of 20 to 30 cm of water. Post-traumatic, postsurgical, and postinfectious hydrocephalus can result from the obstruction of the arachnoid villi, thus preventing adequate CSF reabsorption with subsequent increased intraventricular pressures. In hydrocephalus after cardiovascular accident and in post-traumatic and postsurgical hydrocephalus, the obstruction arises from subarachnoid hemorrhage, whereas in the case of infection, inflammatory changes are responsible for obstructing the arachnoid villi (Fig. 2).

Radiation therapy causes vascular changes in the brain and elevation of CSF protein, scarring, and adhesions, all of which may contribute to the impairment of the CSF reabsorption. Likewise, meningitis causes scarring of the CSF cisterns and absorptive sites, thus leading to chronic hydrocephalus.

The incidence of hydrocephalus following a transcranial approach for a tumor or a vascular abnormality ranges from 10% to 30%. A contemporary estimate of the incidence of CSF leaks following cranial base surgery was reported by Janecka et al. to be 3.6% in a 30-month prospective cohort study of 183 cases. By contrast, Sen et al. reported almost a threefold greater incidence of 8.9% following surgery of the cranial base. However, most studies do not include data indicating whether the hydroceph-
BIBLIOGRAPHY

CONCLUSION

Evidence of HPH can be detected by elevated CSF pressure as measured by lumbar puncture or by CT scan findings, such as dilated temporal horns, and transeptal neyedema. In the presence of HPH, we recommend CSF diversion as an adjunct to the initial fistula repair. The present study suggests that patients at high risk for HPH can be identified prospectively, thus avoiding a second operation. However, our data are preliminary, the study is not randomized, and the period of follow-up is limited. In addition, the sensitivity, specificity, and cost-effectiveness of this management protocol remains to be elucidated.

**BIBLIOGRAPHY**


Carrau et al.: Cerebrospinal Fluid Leaks