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Dedicated to

My parents—Madan and Gulab Lalwani
My in-laws—Rikhab and Ratan Bhansali
My children—Nikita and Sahil
And, most specially to my wife—Renu Bhansali Lalwani
A wonderful partner, friend, mother, community activist
and the smartest internist I know!

Anil K Lalwani

My parents—Ingeborg and Hermann Pfister
My brother and sister—Stefan and Andrea
And, most specially to my beloved Doris
A wonderful partner and my center of inspiration.

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Otolaryngology—Head and Neck Surgery is a dynamic medical and surgical specialty characterized by rapid advances in its scientific foundation and of its therapeutic armamentarium. Simultaneously, there are novel technical and technological innovations that positively impact on patient care. Consequently, Otolaryngology is constantly evolving as new knowledge comes forth and new technologies become available. Recent examples of advances in Otolaryngology include the use of endoscopes to treat a variety of disorders (including middle ear and mastoid disease, CSF Rhinorrhea, and Skull Base Disease), treatment of pediatric airway, new methods to treat chin augmentation, innovative and inexpensive tools to assess gait and posture in the elderly, and robotics in head and neck surgery. The challenge for the busy clinician in the 21st century is to remain abreast of these ever-expanding bodies of knowledge, surgical techniques, diagnostic test, imaging technology, and prosthetics while deeply immersed in their clinical practice. Ironically, this has become even more difficult with the explosion of technologies designed to put information at one's fingertips. This annual periodical, *Recent Advances in Otolaryngology—Head and Neck Surgery*, covering all the subspecialties of Otolaryngology, is designed to make it easy for the clinician to keep current with what is new. Due to its rapid publication cycle, the material is current, topical, and immediately relevant to the clinician. Reviews emphasize clear artwork rendered in color to convey new concepts and surgical approaches. We have assembled an outstanding international editorial board to assist us in this exciting project. Similarly, invited authors are leaders in the field and have made seminal contributions in their topics. We hope that you will enjoy reading this 6th volume as much as we have enjoyed assembling it.

Anil K Lalwani MD
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INTRODUCTION

Cerebrospinal fluid (CSF) rhinorrhea results from an abnormal connection between the subarachnoid space and the nasal cavity. This connection carries with it potential for significant morbidity and mortality due to an increased risk of meningitis, pneumocephalus or other intracranial complications. While etiologies vary, CSF rhinorrhea most often results from trauma, whether accidental or iatrogenic. Iatrogenic causes have increased with the widespread usage of endoscopic sinus surgery to address sinonasal disease, and with the advent of endoscopic skull base surgery. Evaluation has evolved over recent years to include more sophisticated techniques to establish a diagnosis, but localization of the leak sites can be difficult in many cases. When conservative management of CSF rhinorrhea fails, endoscopic surgical techniques may provide a less invasive means to address this issue, especially when compared to more classic open craniotomy approaches to repair.

ETIOLOGY

Traumatic

Etiologies may vary for CSF rhinorrhea, but traumatic injury dominates as the major cause. Multiple reviews of the literature show that approximately 70–80% of cases are the result of either accidental or iatrogenic traumatic injuries. Iatrogenic sources may be the result from endoscopic sinus surgery (ESS), open and endoscopic anterior skull base surgery and various neurosurgical procedures. An increase in iatrogenic sources of CSF rhinorrhea is largely related to the common practice of ESS to address sinonasal disease, and the new and widespread adoption of endoscopic skull base surgery to access intradural pathology. The incidence of major complications from ESS, including CSF leak, however, has been decreasing likely due to increased understanding of paranasal sinus anatomy and increasing
experience. While CSF leak is defined as a major complication, it is rare and now considered to be less than 1% risk with ESS. Potential factors with ESS that may increase the risk of CSF leak include revision surgery, significant polyposis or extensive dissection along the skull base.2

The percentage of postoperative CSF rhinorrhea is higher with neurosurgical procedures, such as transsphenoidal approaches to pituitary tumors. This rate varies between 1.3% and 15.9% for endoscopic approaches, but will likely improve with increased experience and understanding of reconstructive techniques.4,7 It should be noted that other classic neurosurgical procedures are also susceptible to skull base injury resulting in CSF rhinorrhea, such as craniofacial resections and a variety of other approaches to the skull base.

Head trauma resulting in basilar skull fracture represents 7–15% of all skull fractures, with CSF leakage occurring in 2–20% of those injuries.8 These patients may demonstrate rhinorrhea, periorbital ecchymosis, Battle’s sign, and anosmia, as well as other symptoms, if there is lateral skull base injury, such as facial nerve injury, hearing loss and vertigo. Regarding this last point, it should be noted that CSF from the lateral skull base and middle ear may drain through the Eustachian tube into the nasal cavity and present as CSF rhinorrhea. This may be clinically indistinguishable from an anterior skull base leak site, especially if the mechanism is unclear. Therefore, temporal bone trauma, middle ear or lateral skull base surgery can be a potential source for CSF rhinorrhea, and the practitioner should be cognizant of this in order to complete a comprehensive work up.

Nontraumatic

Nontraumatic etiologies of CSF rhinorrhea can be divided into normal and high intracranial pressure (ICP) categories. Etiologies vary and include idiopathic intracranial hypertension (IIH), neoplasms, congenital defects or other erosive skull base processes.2 Congenital sources are generally considered the result of developmental malformation of the skull base.

Special attention should be given to spontaneous CSF rhinorrhea, which occurs without an identifiable source. This entity is given specific attention due to the lower success rate with closure and unclear mechanism. Although the incidence has varied in the literature, some authors report spontaneous CSF rhinorrhea to comprise anywhere from 14% to 46% of all leaks.9-11 Diagnoses that fall in this category are likely to be result from IIH. Work from Schlosser and colleagues has shown that the majority of spontaneous CSF leaks actually fit, closely resemble or are symptomatically and demographically identical to IIH.2,12
Idiopathic intracranial hypertension is a known disorder of increased ICP defined by a pressure that remains elevated above 20–30 cm H₂O or has frequent pressure peaks to these levels. Theories explaining the increase in ICP include decreased absorption or increased production of CSF, and increased venous pressure secondary to stenosis of large cerebral venous sinuses. This elevated ICP over time can result in dehiscences in the skull base and subsequent development of CSF rhinorrhea and/or encephaloceles. Middle-aged, obese females are most often affected, with classic symptoms including headaches, pulsatile tinnitus, papilledema and vision disturbances. IIH can be diagnosed with the modified-Dandy criteria, which include symptoms of increased ICP, elevated ICP (>20 mm Hg for nonobese and >25 mm Hg for obese patients), absence of other neurologic disorders or neuroradiologic findings with the exception of small ventricles and an empty sella, no other causes for elevated ICP and an awake and alert patient (Fig. 7.1 and Box 7.1).

**Figs. 7.1A and B:** Radiographic signs of idiopathic intracranial hypertension, including arachnoid pits (arrows) and an expanded sella (*), are often noted on axial and coronal computed tomography scans (A and B, respectively).
**Box 7.1: Diagnostic criteria for idiopathic intracranial hypertension.**

- Signs and symptoms of increased ICP
- Elevated CSF pressure with lumbar puncture
- No cytologic or chemical abnormalities in CSF
- Absence of focal or other localizing neurologic symptoms
- Absence of neuroradiologic findings other than an empty sella and slit-like ventricles

(ICP: Intracranial pressure; CSF: Cerebrospinal fluid).

**CLINICAL PRESENTATION**

Clear rhinorrhea or a chief complaint of “my nose will not stop running” are hallmarks for CSF rhinorrhea. This can occur anteriorly or posteriorly, and usually worsens with placement of the head in a dependent position or with a Valsalva maneuver. Both of these maneuvers increase clinical suspicion for the disorder, and may facilitate collection of the fluid. Additional symptoms vary considerably depending upon the etiology of presentation. This can be inferred with a history of trauma, recent skull base surgery, known tumor or symptoms consistent with increased ICP in the classic patient such as that seen with IIH (middle-aged and obese female). Symptoms of the latter include headaches, visual disturbance, papilledema and pulsatile tinnitus (as discussed in Nontraumatic in Etiology). CSF rhinorrhea can also easily be confused with other more common causes of nasal drainage, such as vasomotor rhinitis.2

A more serious presentation is intracranial infection such as meningitis, where a patient may exhibit fever, headache, neck stiffness, lethargy and photophobia. The literature has varied regarding the risk of meningitis with a CSF leak, but likely lies somewhere between 2% and 50%.15-17 Eljamel et al. reported the risk of intracranial infection at 1.3% per day for the first 2 weeks after injury, 7.4% per week for the first month, 8.1% per month for the first 6 months and 8.4% per year thereafter.18 Regardless of the numbers, it is accepted that the risk is substantial, increases with duration of leak and can result in considerable morbidity.15

**EVALUATION**

Physical examination begins with identification of CSF drainage. This can be aided by placing the patient’s head in a dependent position, which allows for examination of the laterality of the fluid and aids in collection to examine the color and quality of the fluid. Nasal
endoscopy is also performed to identify any fluid within the nasal cavity, pulsatility or abnormality of the skull base, or presence of masses such as encephaloceles or tumors (Figs. 7.2A and B). The halo sign is a commonly discussed tool for simple identification of CSF in bloody rhinorrhea after trauma, but in practice is more of a historical test and has fallen out of favor. This test is considered positive when
there is a clear ring around a central stain of blood on a white background, but caution should be taken with this finding as tears and saliva may lead to false positives and thus poor specificity (Fig. 7.3).2,19,20

Laboratory

Glucose testing has been used in the past as a rapid diagnostic test for CSF leak due to the belief that concentrations greater than 30 mg/dL in nasal secretions were diagnostic of CSF.2,21 However, much like the halo sign, this has fallen out of use due to a poor sensitivity and specificity.22-24 Additionally, glucose has been detected in airway secretions in those with inflammation or after a high glucose load.22-24 This thought led Oakley et al. to suggest that nasal discharge with high glucose levels might be considered positive for CSF, if the sample contained no blood, the patient was normoglycemic, and there were no signs of airway inflammation, such as with a viral infection.21 These criteria, then, create an obvious impediment to effective use of this testing, and thus have since been largely abandoned in favor of more sensitive, specific, and reliable assays.

Beta-2 transferrin is currently the gold standard for laboratory diagnosis of CSF. Its value lies in its presence in CSF (as well as ocular fluids and perilymph), but not in surrounding airway secretions or other sources of commonly encountered fluids in the upper airway. Due to this, beta-2 transferrin has high sensitivity (97%), specificity (99%) and negative (99%) and positive (97%) predictive values.25 These sensitivities and specificities have been validated by many other studies.21,26-28 As a result, beta-2 transferrin is a frequent part of the practitioner’s armamentarium and published algorithms in the work-up and management of CSF rhinorrhea (Flowchart 7.1). In addition to its accuracy, it is noninvasive and cost-effective with only 0.5 mL needed for testing and several magnitudes lower in cost than other modalities used in the work-up, such as imaging.21
Flowchart 7.1: Proposed algorithm for work-up and management of cerebrospinal fluid rhinorrhea.

1 MRI findings include encephaloceles; MRC can reveal T2 hyperintensity of CSF through the skull or in the paranasal sinuses.

2 Conservative management includes bedrest, lumbar drainage, stool softeners.

3 Findings suggestive of IIH include middle aged obese female with a history of pulsatile tinnitus, headaches, balance and visual disturbances; CT with thinning of the skull base, multiple skull base defects, and arachnoid pits; MRI with partially or completely empty sella, slit-like ventricles, encephaloceles, and dilatation of optic nerve sheaths.

4 High-flow leaks are those with direct connection to the sub-arachnoid space, cisterns, or ventricles.

5 Multiple techniques can be used to repair smaller, low-flow leaks. These materials include autologous tissue, free or vascularized grafts, xenografts/allografts, and bioengineered materials.

6 Poor response to acetazolamide includes a decrease of less than 10 cm H2O, pressure remaining elevated above 25 cm H2O, or starting pressure of greater than 35 cm H2O.

(MRI/MRC: Magnetic resonance imaging/magnetic resonance cisternography; IIH: Idiopathic intracranial hypertension; VP shunt: Ventriculoperitoneal shunt.)
Beta-trace protein, or prostaglandin-D2 synthase, is similar to beta-2 transferrin in its accuracy in CSF identification. It is produced by the leptomeninges and choroid plexus, making it abundant within CSF. Multiple studies have evaluated its accuracy in diagnosing CSF leaks, while also comparing it to beta-2 transferrin. These studies have demonstrated a sensitivity and specificity to routinely approach 100%, with some authors stating this may be superior to beta-2 transferrin due to its quicker turnaround time, higher analytical sensitivity and ability for reliable testing even with blood contamination (unlike beta-2 transferrin). One limitation, however, is that concentrations can be altered by renal insufficiency and bacterial meningitis, thereby limiting its usefulness in those affected by these issues.

Imaging

The importance of imaging cannot be overstated in the evaluation of CSF rhinorrhea. In many cases, it can offer accurate localization of a leak in addition to providing valuable information for surgical planning. Due to this desire for anatomic information and precise localization of the leak site, the choice of imaging modality often favors the test that offers the most data. As such, diagnostic imaging that provides little specific information, such as radionuclide cisternography, has fallen out of favor.

High-resolution computed tomography (CT) is generally the first and most commonly performed imaging study in the work-up of CSF rhinorrhea. The literature varies regarding the sensitivity and specificity of this modality, but commonly approaches 90% and in some studies closer to 100%. Axial and coronal thin cut sections allow detailed assessment of the frontal and sphenoid sinuses, cribriform plates and ethmoid roof. Air-fluid levels, skull base defects, soft tissue (especially in the olfactory cleft) or mucosal thickening with a patient history that is suspicious for CSF rhinorrhea can be suggestive of the site of leakage (Fig. 7.4). Common sources of false negatives include when no bony defect or soft tissue abnormality is seen or when patients have multiple fractures or postoperative defects in the skull base. These images can also be valuable for intraoperative image guidance.

Computed tomography cisternography (CTC) is an additional imaging modality that has been used in the localization of CSF rhinorrhea. This involves injection of contrast through a lumbar puncture followed by a CT scan (Fig. 7.5). Positive findings results when contrast can be seen extracranially or there is an increase of 50% or greater in the Hounsfield units from precontrast and postcontrast in areas with suspicious fluid or soft tissue. This latter finding is pivotal.
for differentiating secretions from true leakage. CTC has proven to be somewhat effective at localizing and confirming a CSF leak, with a sensitivity of around 40% that increases to approximately 90% in active leaks.\textsuperscript{2,37,38} As one can see, though, accuracy is reliant upon an active leak, which is an obvious limitation to those with intermittent low-volume leaks. An additional issue is that intrathecal contrast carries a low risk of seizures, headaches, intracerebral hemorrhage and allergy.\textsuperscript{21} Due to these issues, along with the effectiveness and safety of high-resolution CT and MR cisternography (MRC), CTC is not routinely required and may be best utilized in situations with multiple (e.g. fractures) potential leak sites.\textsuperscript{37}

As mentioned previously, MRC is not as invasive as CTC, in that intrathecal injection is not required. This modality relies on the natural bright signal of CSF on T2-weighted images in magnetic resonance imaging (MRI) to evaluate for leakage extracranially and/or herniation.
of soft tissue through skull base defects. The literature has shown MRC as having a high sensitivity, with some studies approaching 90%, with both active and inactive leaks. Multiple authors have suggested that MRC may be best used in combination with high-resolution CT, as when used together they remain noninvasive and have a combined sensitivity and accuracy of 90–96%. MRC may also be indicated when high-resolution CT fails to identify a leak. Delgaudio and colleagues recently described added utility for MRC with intrathecal gadolinium in difficult to diagnose CSF rhinorrhea, particularly for those patients with intermittent or low volume leaks. The authors utilized repeat delayed imaging, up to 20 hours later, to detect or rule out suspected leaks in a number of clinically challenging scenarios.

**Other**

Radionuclide cisternography (RNC) is considered an option when there is concern for CSF rhinorrhea, but a sample is unable to be obtained for laboratory evaluation. This procedure is a nuclear
management test that involves placement of pledgets into the nasal cavity, intrathecal injection of a radioisotope via lumbar puncture, and subsequent removal of the pledgets after several hours with measurement of the radioactivity. Studies have shown a relatively high sensitivity (76–100%) and specificity (100%). However, RNC should not be confused as a localization study, as a positive response on the pledgets does little to localize the site of the leak. RNC, then, should be reserved for scenarios of a suspected CSF leak where either provocation and outpatient collection of fluid for testing fails (e.g. beta-2 transferrin), or when the clinical and screening radiographic work-up does not coincide.

Intrathecal fluorescein (IF) is a modality that can be used for direct visualization of a CSF leak. The utility of this technique is mainly seen intraoperatively, although it can be used in the outpatient setting for diagnosis. Additional benefits of IF are that it can allow for assessment of complete surgical closure of the defect and identify multiple leak sites when present. This technique involves injection of fluorescein dye into the subarachnoid space via lumbar puncture that is then followed by endoscopic examination, usually in the operating room during a planned repair of the fistula. Sensitivities range from 74% to 90% with a specificity of 100%. Due to the false negative rate, lack of intraoperative fluorescein visualization does not rule out the presence of a CSF leak in and of itself. Therefore, its main utility is in patients with defects that cannot be seen on preoperative high-resolution CT or those with evidence of a defect but without an active leak (Fig. 7.6). It should be noted that intravenous fluorescein has been not approved for intrathecally use in the US. Although complications are rare, they can be severe and include neurotoxicity, seizures and allergic reactions. These effects appear to be mitigated and overwhelmingly avoided by using low concentrations and injection at a slow rate. In diagnostic procedures where intrathecal access is utilized, an opening pressure measurement should be documented, as this may facilitate long-term decision making if the pressure is elevated.

MEDICAL TREATMENT

While antibiotic use might seem logical for meningitis prophylaxis, current evidence does not show any benefit from antibiotics in this setting. In fact, antibiotic use with CSF rhinorrea should be careful and appropriate due to side effects such as allergic reaction, cost, and the possibility for development of antibiotic resistant organisms in the nasopharynx. This points to why early closure of the CSF leak has been advocated by some authors, as this has been shown
to be effective in meningitis prevention, an outcome not seen with antibiotic administration alone.\textsuperscript{50,51} It should also be noted that little evidence exists for routine antibiotic administration in skull base repair, whether intraoperative or postoperative, but nevertheless this is commonly given.\textsuperscript{49,52}

Lumbar drainage is an additional nonsurgical modality that is frequently used both in conservative management and perioperatively to treat CSF rhinorrhea. It is most often utilized as an initial nonsurgical treatment for CSF rhinorrhea resulting from trauma. This involves placement of an indwelling catheter in the intrathecal space to decrease ICP in order to maximize the chance of spontaneous closure or relieve pressure on a skull base repair. Although in theory this may be logical, the benefit is unclear. Multiple authors have shown equal success with repair with and without usage of a lumbar drain.\textsuperscript{53-55} The caveat to this is in the treatment of IIH, where failures are more common and the lumbar drain may be useful to measure ICPs postoperatively to determine which patients may benefit from further therapy to reduce ICP, such as with medications or a shunt.\textsuperscript{39,56-58} It should be mentioned that opening pressures should be measured initially in all those with lumbar drain insertion to document the ICP. Shunts are generally only needed after repair of a CSF leak in those with IIH who have

\textbf{Fig. 7.6:} Intrathecal fluorescein can be seen emanating from the right sphenoid recess. Further investigation revealed an encephalocele along right lateral sphenoid wall.
recurrences post-closure or have very high ICPs that do not respond to medical therapies; however, lumbar drainage can be associated with failure, infectious complications and overdrainage or under-drainage.51,59

As with other treatment modalities that access the intrathecal space, complications such as meningitis, leak from the puncture site, pneumocephalus and brain herniation can occur with a lumbar drain.49 Additionally, multiple studies have noted an increased length of hospital stay in surgical patients with a lumbar drain compared to those without.36,53,60 In a review of the literature, Oakley et al. succinctly concluded that use of lumbar drains should be thoughtfully considered as their use appears to significantly lengthen hospital stay and incur unnecessary costs and potential complications with an unclear benefit.49

Diuretics (e.g. acetazolamide) are also frequently used to decrease ICP when elevated, specifically in those with IIH. Acetazolamide is a carbonic anhydrase inhibitor that reduces production of CSF. Chaaban et al. recently showed a significant decrease in ICP with administration of acetazolamide in those with IIH and CSF rhinorrhea; using a single dose of 500 mg intravenous (IV) and transducing ICP measurements through a lumbar drain catheter, patients’ ICPs dropped on average 10.1 cm H₂O (32 ± 7.4 to 21.9 ± 7.5) after 4–6 hours.61 One issue, however, is that despite its common use to decrease CSF production it is not approved for this purpose in the US. Potential side effects include taste disturbance, electrolyte abnormalities and nephrolithiasis. Furosemide and topiramate are other medications that may decrease CSF production, if acetazolamide is not tolerated.

SURGICAL TREATMENT

Surgery is recommended when conservative treatment has failed for etiologies such as accidental trauma, or as initial therapy in those with spontaneous leaks. Some authors advocate for earlier closure as this has shown to prevent primary and recurrent meningitis, one of the most feared complications of CSF rhinorrhea.50,51 The approach to repair can be either open or endoscopic. While both techniques have proven to be highly successful, endoscopic approaches have become the standard of care given the high success rates, low morbidity, shorter hospital stay, and increasing surgical and technical experience.21 The endoscopic approach avoids the need for craniotomy and retraction of the frontal lobe while reducing the risk of anosmia, seizures, memory deficits and intracranial hemorrhage.2 Success rates only vary slightly in the literature, with most reports having a success rate that approaches and
many times surpasses 90% on the first attempt, and closer to 100%, if a second attempt is needed.\textsuperscript{2,9,11,49,51,62} Success may be influenced by site of leakage, repair type and etiology.\textsuperscript{63}

The overarching principles of defect repair are to correctly identify the site of leakage, prepare the area, seal it and limit morbidity where possible.\textsuperscript{63} There are a variety of materials that can be used for defect repair. These include autologous tissues, allografts, xenografts and engineered or synthetic substitutes.\textsuperscript{2} Repairs can be fashioned in single or multiple layers and placed in a variety of ways, such as an inlay or onlay or combination of the two (Figs. 7.7A and B). Multilayer closures, in theory, can resist pressure gradients in both directions and failure of one layer may be salvaged by the additional layers.\textsuperscript{63} However, the success rate of repair is quite good regardless of the materials used, and little data exist comparing these materials in their varying combinations.\textsuperscript{2,49}

Autologous tissues are the mainstay of repair. Commonly used grafts include mucosa (free or pedicled grafts), bone, cartilage, fascial and fat grafts. The advantages of these materials include their biocompatibility, low cost, availability and rapid incorporation into surrounding tissue.\textsuperscript{2} Bone and cartilage grafts are recommended mainly in cases of large skull base defects with herniating meninges and brain.\textsuperscript{54} These forms of rigid support may be especially important in those with elevated ICP, or with inflammatory sinonasal disease where future surgery may be needed.\textsuperscript{59,63,64} Bone cements can also be used in skull base repair, but are generally avoided in our practice due to risk of infection, microfracturing due to CSF pulsations or in high-flow leaks. Fat grafts are often described for obliteration of a defect in an area such as the sphenoid sinus, with most studies showing a success rate close to 100%.\textsuperscript{49,54} Smaller, well-placed fat grafts can be used to precisely fill in defects, spanning layers and providing tissue for long-term closure with high success rates.\textsuperscript{65}

Free mucosal grafts have also shown to be very successful. Free grafts can be harvested from the turbinates, septum and nasal floor, and are relatively easy to harvest and place due to lack of need to maintain a vascular pedicle. The morbidity of harvest is particularly low, especially if it is removed from a turbinate that was excised as part of the surgical procedure. One point with a free graft, though, is that contraction up to 20% can occur in the postoperative period that can compromise the ability of the graft to integrate into the surrounding mucosa and thus lead to failure.\textsuperscript{56}

The nasoseptal flap deserves specific mention due to its ability to repair large (>3 cm) and high-flow defects, relatively low donor
site morbidity, versatility in covering the skull base and reliable and hardy vascular supply. The nasoseptal flap is pedicled off of the posterior septal artery, which is a terminal branch of the sphenopalatine artery. Vascularized flaps are particularly useful for those with a prior history of radiation therapy or when it is expected postoperatively, high-flow leaks and large skull base defects.
The differentiation between low-flow and high-flow leaks is not well-defined, but generally can be considered those areas with a direct connection to a CSF cistern or ventricle, or when intracranial hypertension is present. With the use of this flap, the incidence of postoperative CSF leak after an intraoperative high-flow leak is repaired decreases dramatically from 20–30% to approximately 5%.\textsuperscript{2,62,67}

Allografts and xenografts are excellent options for patients in that they prevent the morbidity associated with harvest of grafts such as fat, bone or vascularized grafts. These latter grafts require additional incisions, and healing of donor areas can be complicated by hematomas, infections and other wound complications. A commonly used allograft is acellular dermis, which has been used with success rates approaching 90–100%.\textsuperscript{2,57,58} Advantages include no operative time required for graft harvest, low propensity for contraction or shrinkage and ease of use.\textsuperscript{2} Additional grafting materials that have gained significant popularity are collagen-based dural replacement products. These products are created to form a porous matrix that is optimized to allow ingrowth of fibroblasts, angiogenesis and new collagen formation, all in order to become fully incorporated into the surrounding tissue while limiting associated inflammation.\textsuperscript{2,68}

Nasal packing, glues and sealants are frequently used to support grafts once in place, especially if these are placed as an overlay. In a meta-analysis by Hegazy et al., these adjunctive measures were commonly used, but did not appear to have a significant effect on the outcome of the repair.\textsuperscript{49,54} In fact, sealants and glues are often used off-label, and studies examining their safety and efficacy are very limited.\textsuperscript{2} Despite this, their use is common practice, and is advocated by many surgeons as they have been shown to add strength to the repair in an \textit{ex vivo} animal model.\textsuperscript{69}

Lastly, it is worth considering bariatric surgery for those with obesity and IIH. Although not part of the surgical reconstruction of a skull base defect, its contribution may be substantial in preventing or treating spontaneous CSF leaks in those with IIH, minimizing future recurrences and benefiting the patient’s overall health.\textsuperscript{70} Initial treatment for IIH includes conservative measures such as lifestyle modification that includes diet and exercise. However, this is often very challenging for these patients, especially with ongoing debilitating symptoms of IIH that may limit their ability to make lifestyle changes.\textsuperscript{71} In a systematic review by Handley et al., bariatric surgery with subsequent weight loss was shown to be highly effective in reducing symptoms associated with IIH.\textsuperscript{71} More interestingly,
this may be effective at preventing spontaneous CSF leaks, but data regarding this point are limited to case reports and therefore should be interpreted with caution.⁷²

**CONCLUSION**

Cerebrospinal fluid rhinorrhea continues to carry the potential for significant morbidity, in addition to associated risks of meningitis and other intracranial complications. Trauma as a whole dominates as the source of CSF rhinorrhea, and while accidental injuries still contribute, iatrogenic sources may become more common with the expansion of ESS and endoscopic skull base surgery. The initial goal for patients suspected to have CSF rhinorrhea includes documentation of CSF presence and attempted localization of the site(s) of leakage. The importance of these two steps cannot be overstated. Beta-2 transferrin has proven to be a very reliable test to confirm the presence of CSF within nasal drainage. Imaging has also continued to evolve over recent years to include more sophisticated techniques, but despite this, high-resolution CT scan and MRI are the mainstays for identifying a defect and planning surgical repair. Regarding repair, a multitude of reconstructive options exists, including autologous tissues (fat, bone, cartilage and fascia lata), xenografts/allografts, bioengineered collagen-based grafts and free and vascularized mucosal grafts. Regardless of the variety, these materials have shown little difference in success rate with CSF leak closure, and for the majority of cases surgeon preference will dictate decision-making.

Patients with IIH or elevated ICP deserve careful attention. These patients have higher recurrences rates and the propensity to have multiple defects, making them have an overall more complex course. In addition to confirming a leak and localizing and repairing it, these cases require perioperative and ongoing management of their increased ICP with lumbar drainage, medications to lower ICP, and if needed, shunting. Lastly, bariatric surgery is worth considering in patients with obesity, as this is not only likely to lower ICP but also significantly improve their overall quality of life.

**REFERENCES**

Management of Cerebrospinal Fluid Rhinorrhea


