Contemporary Trends in the Management of Posttraumatic Cerebrospinal Fluid Leaks

Moustafa Mourad, MD[1] Jared C. Inman, MD[2] David M. Chan, MD[3] Yadranko Ducic, MD, FRCSC, FACS[3]

[1] Department of Otolaryngology, New York Eye and Ear Infirmary of Mt. Sinai, New York, New York
[2] Department of Otolaryngology, Loma Linda University, Loma Linda, California
[3] Otolaryngology and Facial Plastic Surgery Associates, Fort Worth, Texas

Address for correspondence Yadranko Ducic, MD, FRCSC, FACS, Department of Otolaryngology and Facial Plastic Surgery, 923 Pennsylvania Avenue, Suite 100, Fort Worth, TX 76104 (e-mail: yducic@sbcglobal.net).

Craniomaxillofac Trauma Reconstruction 2018;11:71–77

Abstract

The objective of this review is to provide an overview on the diagnosis and management of traumatic cerebrospinal fluid (CSF) leaks. This comprehensive review explores controversies associated with the management of CSF leaks as well as a review of the most contemporary literature. The scope of this article covers both traumatic CSF leaks of the middle and anterior cranial fossae.

Keywords
- skull base fracture
- cerebral spinal fluid leak
- review

Traumatic compromise to the dural lining with leakage of cerebrospinal fluid (CSF) may increase a patient's likelihood of developing meningitis with subsequent mortality rates of 10% should infections or fistulas go unrecognized.[1] CSF leakage may be spontaneous, iatrogenic, or occur in the setting of penetrating or closed head trauma. Iatrogenic CSF leaks often times are repaired immediately when identified intraoperatively, or may resolve with observation in the immediate postoperative period. Spontaneous CSF leaks may also be amenable to observation and conservative management.[2] In the setting of trauma, CSF leaks may occur in 2% of all closed head trauma and up to 30% of basilar skull fractures.[2–4] In posttraumatic CSF leaks, especially of the anterior skull base, 10 to 25% of patients will develop meningitis. The management of these posttraumatic CSF leaks may vary considerably depending on associated intracranial injuries, site of leakage, and the extent of defect.[5] Management options range from observation in anticipation of spontaneous resolution to surgical endoscopic or open repair.[6,7]

Historically, two-thirds of traumatic CSF leaks will resolve spontaneously within 1 month. This is especially true in the traumatic lateral skull base trauma, or cranio-aural leak. Famously, Brodie and Thompson showed in 820 cases of temporal bone fractures that 122 had CSF leak and 95 of these closed spontaneously in less than 7 days and 21 more closed in less than 14 days and only 5 persisted.[6] Conversely, CSF leaks of the anterior skull base do not display the same expected conservative management closure rates, which can be readily seen in a review of 81 consecutive CSF leaks comparing the lateral and anterior CSF posttraumatic leak where 14 out of 53 leaks closed spontaneously, compared with 17 out of 28 lateral skull base leaks.[8] Should a persistent cranio-sino fistula form with persistent or intermittent leak, these patients are at an almost inevitable risk of developing meningitis—a risk that persists for decades after their trauma. In a review, one study showed that the cumulative risk of developing meningitis within 10 years of a CSF leak skull base trauma is reduced from 85 to 7% when surgery is able to identify and close the leak initially.[9] The objective of this review is to provide an overview to the etiologies, diagnosis, and management of posttraumatic CSF leaks with insight into contemporary trends and controversies.

Anterior Cranial Fossa

Anatomy

The anterior cranial fossa extends from the posterior wall of the frontal sinus anteriorly to the anterior clinoid process and

received
February 2, 2016
accepted after revision
March 25, 2016
published online
November 1, 2016

DOI https://doi.org/10.1055/s-0036-1584890.
ISSN 1943-3875.

the planum sphenoidale posteriorly. The base of the anterior cranial fossa is formed by the ethmoid, sphenoid, and frontal bones. The anterior cranial fossa may be further subdivided into medial and lateral components. The medial portion includes the cribriform plate of the ethmoid bone, extending from the posterior surface of the frontal sinus anteriorly to the planum sphenoidale posteriorly. The lateral portion is formed by the frontal bones and the lesser wing of the sphenoid bone.[10] The anterior cranial fossa houses the frontal lobe in addition to the olfactory tract and bulb. Its close proximity and intimate relationship to the orbit, paranasal sinuses, and intracranial contents may pose specific challenges in the management of posttraumatic leaks in this region.

Many classification systems have been proposed in defining anterior cranial fossa injuries.[5,10,11] Despite the various classification system, approach to repair of CSF leaks in this region should be centered on attenuating the risks of meningitis, preventing the formation of mucoceles, preservation of frontal sinus tract flow, as well as preventing delayed complications such as brain sagging.[12] Management of fractures in this region can be dictated by the presence or absence of frontal sinus involvement.[10] However, it is important to recognize that these fractures may not occur in isolation and may involve multiple regions.[5]

Frontobasilar Fractures

Diagnostic Procedures

Frontobasilar fractures that result in CSF leak likely involve the posterior table with compromise to the dura, resulting in clear unilateral rhinorrhea. The most frequent location of CSF leak leading to rhinorrhea involves the ethmoid-cribriform plate.[8,9] Frontal sinus outflow obstruction from swelling, posttraumatic bone fragments, or blood clots may temporarily prevent CSF rhinorrhea, making timely clinical recognition difficult.[13] Diagnosis is usually through combined clinical exam as well as high-resolution computed tomographic (CT) scans. CT scans using 1-mm cuts can identify minor bony defects that may support the diagnosis of a CSF leak—axial, coronal, and sagittal views are necessary to evaluate the frontobasilar skull base. High-resolution CT images with multiplanar views provide a sensitivity of visualization of the bony defects responsible for the CSF leak in 88% of patients.[14]

In a review of high-resolution CT with multiplanar reformations, the specificity of CT for leak was 91%, and the ability to locate the leak within 2 mm (as confirmed on endoscopic repair) was 75%.[15] Furthermore, fluid within the frontal sinus, pneumocephalus, and intradural air may be indirect findings, further supporting the diagnosis of a CSF leak when obvious displaced bone fragments are not present.[16]

CSF rhinorrhea may not be clinically evident in all cases, particularly in the setting of an intermittent fistula or low flow leaks. Ancillary laboratory assays including β-2 transferrin analysis of rhinorrhea may help in further supporting a diagnosis.[17] Limitations to β-2 transferrin, however, include the need for significant quantity for analysis which may be difficult to obtain in low flow leaks, as well as delay in analysis which may take several days. However, other CSF properties including glucose and protein counts, in addition to low magnesium and chloride content may facilitate diagnosis, while results of β-2 transferrin are pending. Certain physical exam maneuvers, such as a leaning over Valsalva, may help in some cases, and others will require patient at-home observation with attention to nasal rhinorrhea for collection and submission to the laboratory. In cases where physical exam, laboratory findings, and CT are negative, magnetic resonance imaging (MRI) may be of useful. MRI can show CSF pooling in sinuses directly underlying the fracture, dural injury, and most importantly the associated brain injury and fluid collections such as abscesses. Use of radionuclide cisternography may further assist in making a diagnosis with a sensitivity of 92% for active leaks and 40% for inactive leaks.[9] MRI cisternography has been found to be superior to CT cisternogarphy.[18]

Special attention should be given to fractures involving the lateral sphenoid sinuses in posttraumatic patients, where CT angiography or magnetic resonance angiography is often utilized to ensure that the intracranial carotid has not been compromised or is at future risk for developing a pseudoaneurysm.[19] In other refractory cases, or cases where imaging has been nondiagnostic, endoscopic surgical sinonasal exploration with navigation and adjunctive use of intrathecal fluorescein can have a sensitivity of up to 97%.[20]

In summary, a systematic review of CSF leaks encompassing 68 studies by Oakley et al showed that β-2 transferrin is the most reliable confirmatory test with high-resolution CT being the first-line recommendation for leak identification.[21] Should CT not show the source, then MRI cisternography would be the next diagnostic test with the highest accuracy that one may want to consider if surgical endoscopic exploration is planned. This may be performed in addition to intrathecal fluorescein for improved localization.[20] Should MRI cisternography not be available, operative exploration is an option, as is combining the review of high-resolution CT with MRI which should yield a combined sensitivity of 97%.[22] Recently, the role of MRI using three-dimensional fast-spin (3D FSE) T2-weight imaging (T2WI) and 3D steady-state free precession (FIESTA) sequences was determined to be a noninvasive alternative for leak localization with promising results for inner ear malformation.[23] Their role in traumatic CSF leaks is yet to be substantiated but may be considered as an alternative prior to invasive localization techniques or directed operative interventions.

Conservative Management

Evolving trends in the management of posttraumatic CSF leaks of the anterior skull base, specifically involving frontal sinus, show an expanding role for conservative management.[24–26] Such measures include the use of ventriculostomy, lumbar drains, and medical management with stool softeners, bed rest, and head of bed elevation. The goal of conservative management is to reduce CSF pressures allowing for spontaneous healing and resolution of the site of leakage. To date, according to the systematic review by Oakley et al in 2015, there is no aggregate evidence level which can be generated from the available literature to review many adjunctive historic conservative measures.[27]

In 2001, a survey of otolaryngologists managing CSF leaks from skull base trauma reported that two-thirds were using lumbar drains routinely.[28] In 2012, Psaltis et al could not ascertain from their meta-analysis the number of cases using lumbar drains, their indications, or their effectiveness.[29] Most literature reviewed in this article identified the decreasing use of lumbar drains, but no studies to our knowledge could be found worth including for recommendation purposes. However, commonly cited indications include large defects, coexistent meningoencephaloceles, and poor neurological exam requiring continuous intracranial pressure monitoring. Prudent use of lumbar drains should be considered due to their unproven efficacy and the fact that they introduce an indwelling foreign body into another sterile body site that may cause infection and persistent leakage. Lumbar drains also create a negative pressure vacuum and if the skull base defects are not sealed off from the sinonasal air cavities, air can be pulled through defects, contributing to pneumocephalus and herniation if watertight closure or packing is not optimal. Cost is also a consideration, as there is evidence that lumbar drains increase hospital length of stay.[21] Elevations in costs have been found to correlate with length of hospital stay in patients managed with lumbar drains when used both during conservative management cases and in conjunction with surgical interventions.[30,31] Increased in cost has also been seen in association with readmissions due to complications in lumbar drains.[32] Increase in lumbar drain–associated costs, however, may be associated with use in more complicated patients, with greater extent of injury, as well as other comorbid traumatic complications, necessitating studies with appropriate patient-matched cost analysis.

Overall, Oakley et al found in their 2015 systematic review of 67 studies managing CSF rhinorrhea, 14 studies adequately addressing the use of lumbar drains. They concluded, with an aggregate grade of evidence C and acknowledgment, that the evidence is limited, and suggested that lumbar drains do not contribute to successful repair.[27] In our interpretation of the literature overall, it is less common for lumbar drains to be used in managing CSF leaks, whether created from surgery or trauma. However, in specific cases, decreasing CSF pressure can theoretically aide in sealing leaks with lower rates of fistula formation. Drainage of CSF fluid likely plays a role in a certain patient cohort, but this cohort is inadequately defined thus far and further research is needed. CSF drainage must be done with close neuro observation, checking for mental status and for volume-related headaches, and the possibility of air and bacteria pulling through the dural defects must be considered and followed with serial imaging.

Recently, the role of acetazolamide has been evaluated in the management of CSF leaks.[33] Acetazolamide is a carbonic anhydrase inhibitor that reduces CSF production and has been used in the management of idiopathic intracranial hypertension. Gücer and Viernstein found that at 4 g/day, intracranial pressure was significantly reduced.[33] Chaaban et al provided the first prospective evaluation of acetazolamide use in CSF leak associated with intracranial hypertension in addition to CSF diversion methods and found there was a significant decrease in intracranial pressure within 4 to 6 hours of administration.[34] The role of acetazolamide seems promising due to its direct effects on CSF production and intracranial pressure, but their remains a paucity in the literature, substantiating its use in posttraumatic CSF leaks.

Indications for nonoperative interventions include noncomminuted fractures or fractures with minimal displacement. In the high-resolution CT era, other authors classify displacement as greater than one table width as opposed to a historic strict cutoff of 1 mm.[35] However, if spontaneous resolution of CSF leaks does not occur within 7 days of nonsurgical intervention, most authors would recommend definitive surgical treatment due to increased risk of ascending intracranial infection.[35,36] After 7 to 10 days of persistent fistula, there is an 8- to 10-fold increased risk of the development of meningitis.[37]

Operative Management

Endoscopic management: Recent advances in transnasal endoscopic sinus technique and technology have led to widespread use and acceptance for use in traumatic CSF repairs involving the frontobasilar skull base.[38] It should be noted, however, that paramount to successful endoscopic repair of traumatic CSF leaks is the accurate diagnosis and localization of site of leak, as well as appropriate characterization of defect size.[39] Many technological and technical advances have been made since endoscopic repair was first described in the early 1980s and as reported in a review of endoscopic cases through 2012 by Psaltis et al, the literature shows 1,778 fistula repairs in 55 studies with an average endoscopic closure rate of 90% for primary repairs and 97% for secondary repairs with a complication rate of 0.03%.[29] Higher repair failures may occur under circumstances in which the site of leak is not fully mapped, the size is underestimated, or a secondary leak goes unrecognized. To help better localize the site and extent of leaks, some authors advocate the use of intraoperative fluorescein.[39] Contraindications include the presence of concurrent intracranial lesions, severe comminution of the skull base, large dural tears, and fractures with significant lateral extension.[40] Medially based defects located within or surrounding the frontal recess are most amenable to endoscopic repair.[41,42] In 2014, Lobo et al reviewed the contemporary literature from 2011 to 2014 and summarized the technical advances and new technologies, helping surgeons expand their endoscopic armamentarium in dealing with anterior skull base pathology and CSF leaks.[43]

Surgical technique and approaches to closure are varied, with no clear consensus existing with regard to optimal methods. However, vital to the successful endoscopic repair of CSF leaks arising in the frontal basilar skull base or frontal sinus is a multilayer closure through the use of grafts (muscle, fat, cartilage, fascia, or bone) or mucosal flaps.[44] Some authors advocate the use of intradural underlay grafts.[45] Free autograft materials are available, but allografts are preferred to help minimize resorption and infection risk. Allografts of mucosa, fascia, muscle, and fat plug grafts have all been described with relatively equivocal success rates—both in isolation and in combination. Larger defects seem to have better success rates overall in the literature with larger grafts, underlay techniques, or the use of fascia. Multilayer reconstruction is superior to single layer. For larger bony defects, rigid grafts such as bone can be utilized to provide rigid support, followed by onlay grafts with a pedicled mucosal flap.[46,47] Pedicled vascular grafts allow for more robust reconstructions with higher rates of success when compared with nonvascularized grafts, especially as defect size increases.[21] These vascularized flaps should result in greater than 90% closure rates. Moreover, in a recent literature review, high-flow CSF leaks have a postoperative CSF leak closure rate of 94% with vascularized grafts, compared with 82% in free tissue grafts.[48] In 2015, Clavenna et al reviewed the regionally available pedicled flaps for anterior skull base dural defects, recognizing the most often utilized flap as the nasoseptal flap.[49]

For more extensive defects, the endoscopically harvested and delivered pericranial flap may be considered when a larger coverage option is needed. Biosynthetic sealants such as fibrin can also be utilized to facilitate adherence between layers, in addition to use of Gelfoam for added support.[44,46] With overlay and underlay techniques, one must consider intracranial pressure and gravity with graft placement and consider the addition of tissue glues, temporary absorbable packing, and formal packing to augment reconstructive techniques.

The use of prophylactic antibiotic therapy is yet to be validated in the literature in the prevention of intracranial infection as a complication frontobasilar and frontal sinus fractures.[50] Despite the paucity of literature, most surgeons report the use of perioperative antibiotics directed at gram-positive organisms.[51] In 2012, a systematic review of 1,778 CSF fistulas in 55 studies by Psaltis et al, only 23 studies recorded their antibiotic routines. Four studies used only perioperative antibiotics, while 18 studies reported differing ranges of use from 2 to 14 days, with most studies stating antibiotics were used because of nasal packing or concurrent lumbar drain.[29] In 2015, a systematic review by Oakley et al showed that the literature does not support the routine use of prophylactic antibiotics in the management of CSF rhinorrhea. Ten studies met criteria with an aggregate grade of evidence B.[21] Of note, this study does not examine the routine use of the standard surgical perioperative antibiotic dosages for the prevention of routine surgical infection risk.

Individual surgeons or institutions should take caution in deciding their routine antibiotic use based on these meta-analyses. Although they represent the best data to date, it is our opinion that antibiotic studies lack in their individual quality control and their individual indications for prophylactic antibiotic use—with most studies being subjective in their cohort selection or severely lacking in power. It is our interpretation that most surgeons still use perioperative antibiotics (which may extend from surgery to 24 hours postoperatively), but are trending away from using longer-term antibiotics as a routine in all patients. In our opinion, most surgeons would still advocate antibiotics for infected fields, lack of watertight closure, inadequate repair, or other concerning high-risk patient factors for postoperative infections. A major deficit in the postsurgical antibiotic literature is that to increase the power of studies, cohorts of patients are grouped together which should likely be in different cohorts. Overall, the authors agree with the meta-analysis that in low-risk surgical patients, with a small dural tear, adequately repaired in a timely fashion, with proper postoperative care, perioperative antibiotic use is likely beneficial but longer-term use should be reserved for surgeon or patient-specific risk factor concern.

Overall rates of success for transnasal endoscopic approaches are reported between 80 and 100%.[52] Recently, a meta-analysis of 289 CSF leaks by Hegazy et al reported a success rate of 90% ($n = 259$) following a single attempt at closure, with 17 of 30 (52%) persistent leaks closed after second attempts. Overall, analysis indicated a 97% successful closure rate.[38] This is similar to the findings by Psaltis et al of 90% closure on first attempt.[29]

Transcranial or transfacial (open) management. Open surgical repair is often times indicated in the setting of large cranial base fractures, extensive bony defects, extensive comminuted fractures, massive CSF rhinorrhea, open cranial trauma, concurrent intracranial lesions and hematomas, or destruction of the paranasal sinuses.[8] Furthermore, open approaches may be necessitated when endoscopic approaches are contraindicated, or in the setting of failed endoscopic repair.[8] Open approaches further have the added benefit of allowing operative exploration with access to intracranial-associated findings, as well as facilitating single-stage combined reconstruction of concurrent maxillofacial trauma, if open access from above is required.[53] The goals of open repair are the reconstruction of the skull base, providing brain parenchyma support as well as preventing delayed complications including mucocele formation, intracranial infections, as well as recurrent CSF leaks.[5]

Open approaches can be achieved by transfacial, subcranial, or transfrontal craniotomies.[54] Reconstructive options include the use of pedicled pericranium, pedicled or free temporalis fascia, or free tensor fascia lata grafts. Other options include further pedicled flaps or free tissue transfer.[1,8] There is a paucity in the literature with respect to ideal reconstructive methods, likely due to variability in defect size and surgeon preferences, making comparisons difficult. In a study by Neligan et al, a direct comparison between regional and free tissue transfers was made, with lower rates of wound complications, flap loss, CSF leak, and ascending infections found in the microvascular free flap group.[55] In another study by Califano et al in 2003, outcomes between regional and free tissue flaps was also compared, with no difference in major complication rates, despite free tissue transfers being utilized in more complex defects.[56] Microvascular free flaps also have the added advantage of providing robust multilayer—dermis, fat, fascia, muscle—vascularized tissue that is invaluable in larger defects that are at increased risk for ascending infections.[57,58] Microvascular repair with larger bulky flaps may also enhance closure of intracranial dead space in larger defects, preventing future complications such as sagging brain parenchyma. Therefore, in larger anterior cranial base defects, free tissue transfer may provide improved outcomes, especially when there is associated tissue loss, such as orbital contents or skin avulsion injuries.[1,55,56]

In the setting of CSF leaks that require open repair, frontal sinus cranialization is often necessary to prevent recurrence of the leak.[59] Timing of open surgical repair is often based on comorbid injuries and need for emergent interventions, as well as consideration for risk of developing intracranial infections. In the absence of indications for emergent intervention (brain herniation, hematoma, abscess), some authors advocate repair within 1 week of trauma.[58,60] Beyond 1 week, there is evidence suggesting an 8- to 10-fold increase in intracranial infection.[6] The use of prophylactic antibiotics in open repair remains controversial, with only a single identified double-blinded study demonstrating no added benefit.[61] Antibiotic indications should be driven by associated findings or patient presentation—fever, white blood cell elevation, signs of meningitis, abscess, or purulent drainage from the subsites around the CSF fistula.

Middle Cranial Fossa

Anatomy

The middle cranial fossa is predominantly composed of the greater wing of the sphenoid bone anteriorly and the temporal bone posteriorly. The parietal bones form its lateral boundaries. It extends from the posterior margin of the lesser wing of the sphenoid anteriorly to the clivus and the petrous portion of the temporal bone posteriorly.

There have been many proposed classification systems to describing middle cranial fossa and temporal bone fractures. Most recently, classification of the otic capsule (otic capsule sparing vs. otic capsule violating) seems to have greater clinical applicability.[62] Otic capsule violating fractures are four times more likely to develop CSF leakage, in addition to twice as likely having facial nerve paralysis, and seven times more likely to have hearing loss.[62]

Temporal Bone and Middle Cranial Fossa Fractures

Diagnostic Procedures

Diagnosis of posttraumatic CSF leaks involving the middle cranial fossa and the temporal bone is usually made through combination clinical history and physical examination, in conjunction with imaging studies. In the largest series of temporal bone fractures, Brodie et al found that of 122 patients with CSF fistula 97 presented with otorrhea, 16 with rhinorrhea, and eight with otorhinorrhea. A single patient had presented with meninigitis.[6] High resolution CT scanning can also be utilized with 87% accuracy in predicting the presence of CSF leak.[20] MRI may also assist in the diagnosis of CSF leak, with the added advantage of distinguishing brain parenchyma in the presence of herniation. MRI is recommended for defects larger than 2 cm, due to the increased associated risk of brain herniation.[63] Cisternography may be used with magnetic resonance or CT imaging modalities assisting in localization of leak site, but are not routinely used due to their invasive nature.[9,14] Ancillary laboratory assays include β-2 transferrin found in CSF fluids, with reported sensitivity and specificity of 99% and 97%, respectively.[64] However, β-2 transferrin testing is limited because it takes up to 2 days for results to return, and the amount of fluid needed for accurate diagnosis.[64]

Intrathecal fluorescein may also be utilized intraoperatively, or preoperatively to further assist in site localization–but only when necessary, as this is still an unrecognized off-label use of fluorescein with side effects. Additional testing including pure tone audiometry and electrophysiological testing of the facial nerve is also warranted to assist in directing operative management if needed. Of note, any patient requiring operative exploration should have a preoperatively documented facial nerve and tuning fork exam performed.

Conservative Management

In the absence of indications for operative intervention (concurrent injuries, facial nerve paralysis, hearing loss) nonsurgical management may be considered. Conservative management of traumatic middle cranial and temporal bone fractures is centered around minimizing intracranial pressures to facilitate spontaneous resolution. Measures include total bed rest, head of bed elevation, stool softeners, as well as avoiding Valsalva, sneezing, or nose blowing.[6] Conservative management can be tried for the first 7 to 10 days following injury, with other options being considered thereafter due to the increase risk of ascending infection.[65] CSF diversion techniques, including lumbar drains or ventriculostomies, can be considered prior to operative intervention in nonresolving leaks.[14] Overall, spontaneous closure with conservative management can occur in 95 to 100% of cases, with 78% occurring in the first 7 days.[6,62,66]

Several studies indicated that use of prophylactic antibiotics in patients with known CSF leaks in the setting of temporal and middle vault trauma does not attenuate the risk of infection.[61,67] However, in a pooled meta-analysis by Brodie over a 25-year period, they demonstrated that prophylactic antibiotics did reduce the risk of meningitis. They highlighted that individual studies did not demonstrate any statistical differences between treated and nontreated groups due to small population sizes.[37] Furthermore, it was determined that there was an increased risk of ascending infections in the presence of concurrent infections.[6] It is the authors' opinion that patients with an ongoing CSF leaks into a contaminated space be treated with antibiotics until the leak has stopped to prevent ascending infections. The ideal length of treatment with antibiotics following CSF leak resolution is not clear. Routinely, continuing antibiotics for 7 days after active leaks have resolved has been our combined practice; however, we concede that shorter courses are likely as effective. For example, 72 hours after the leak has stopped would be considered a viable shorter course—this is an area where further research is needed.

Operative Management

Considerations for operative intervention and surgical approach in posttraumatic CSF leaks of the temporal bone and middle cranial vault include status of hearing in affected/unaffected ears, facial nerve function, presence of brain herniation, and location of fistula.[6] Hearing preservation should be attempted if possible, particularly in a better hearing ear. Ipsilateral profound hearing loss involving the otic capsule should be managed with obliteration of the mastoid and middle ear cavities.[68,69] In circumstances in which the CSF leak is ipsilateral to a better hearing ear, approaches to repair should be conservative and aimed at hearing preservation. Sites of leakage in the posterior cranial fossa or involving the tegmen can be managed with fascial underlay or overlay grafting and obliteration of the mastoid and antrum, usually with a free fat graft.[70] Larger defects involving the tegmen tympani, or petrous ridge, can also be approached through a standard middle cranial fossa craniotomy.[70] For leaks involving brain herniation, Brodie and Thompson advocated for a three-layer closure including extradural inlay graft using temporalis fascia, placement of an intracranial bone graft, and finally an extracranial onlay graft with fascia.[6]

Conclusion

The management of traumatic CSF leaks has evolved over the past several decades. Endoscopic techniques have come to the forefront in the management of anterior cranial fossa defects, while open approaches are reserved for complicated defects and failure. A common theme in modern repair is the use of multilayered closure with vascularized tissue, such as the pericranial flap or nasoseptal flap. For large, complicated defects, free tissue transfer provides a reliable, multilayered construct for repair. Unfortunately, evidence for the routine use of antibiotics and lumbar drains is lacking and deserves more attention.

Note
None of the authors has any conflicts of interest, financial or otherwise. The authors received no financial support. All authors contributed substantially to, and approve of, this manuscript.

References

1 Inman J, Ducic Y. Intracranial free tissue transfer for massive cerebrospinal fluid leaks of the anterior cranial fossa. J Oral Maxillofac Surg 2012;70(5):1114–1118
2 Rao N, Redleaf M. Spontaneous middle cranial fossa cerebrospinal fluid otorrhea in adults. Laryngoscope 2015:254–261
3 Lewin W. Cerebrospinal fluid rhinorrhea in nonmissile head injuries. Clin Neurosurg 1964;12:237–252
4 Mendizabal GR, Moreno BC, Flores CC. Cerebrospinal fluid fistula: frequency in head injuries. Rev Laryngol Otol Rhinol (Bord) 1992; 113(5):423–425
5 Archer JB, Sun H, Bonney PA, et al. Extensive traumatic anterior skull base fractures with cerebrospinal fluid leak: classification and repair techniques using combined vascularized tissue flaps. J Neurosurg 2016;124(3):647–656
6 Brodie HA, Thompson TC. Management of complications from 820 temporal bone fractures. Am J Otol 1997;18(2):188–197
7 Daele JJ, Goffart Y, Machiels S. Traumatic, iatrogenic, and spontaneous cerebrospinal fluid (CSF) leak: endoscopic repair. B-ENT 2011;7(Suppl 17):47–60
8 Scholsem M, Scholtes F, Collignon F, et al. Surgical management of anterior cranial base fractures with cerebrospinal fluid fistulae: a single-institution experience. Neurosurgery 2008;62(2):463–469, discussion 469–471
9 Eljamel MS. Fractures of the middle third of the face and cerebrospinal fluid rhinorrhoea. Br J Neurosurg 1994;8(3):289–293
10 Piccirilli M, Anichini G, Cassoni A, Ramieri V, Valentini V, Santoro A. Anterior cranial fossa traumas: clinical value, surgical indications, and results-a retrospective study on a series of 223 patients. J Neurol Surg B Skull Base 2012;73(4):265–272
11 Madhusudan G, Sharma RK, Khandelwal N, Tewari MK. Nomenclature of frontobasal trauma: a new clinicoradiographic classification. Plast Reconstr Surg 2006;117(7):2382–2388
12 Eloy JA, Choudhry OJ, Christiano LD, Ajibade DV, Liu JK. Double flap technique for reconstruction of anterior skull base defects after craniofacial tumor resection: technical note. Int Forum Allergy Rhinol 2013;3(5):425–430
13 Sailer HF, Grätz KW, Kalavrezos ND. Frontal sinus fractures: principles of treatment and long-term results after sinus obliteration with the use of lyophilized cartilage. J Craniomaxillofac Surg 1998;26(4):235–242
14 Bell RB, Dierks EJ, Homer L, Potter BE. Management of cerebrospinal fluid leak associated with craniomaxillofacial trauma. J Oral Maxillofac Surg 2004;62(6):676–684
15 La Fata V, McLean N, Wise SK. CSF leaks: correlation of high-resolution CT and multiplanar reformations with intraoperative endoscopic findings. AJNR Am J Neuroradiol 2008;29(3):536–541
16 Sakas DE, Beale DJ, Ameen AA, et al. Compound anterior cranial base fractures: classification using computerized tomography scanning as a basis for selection of patients for dural repair. J Neurosurg 1998;88(3):471–477
17 Oberascher G, Arrer E. [Initial clinical experiences with beta 2-transferrin in oto- and rhinorrhea]. HNO 1986;34(4):151–155
18 Wang X, Xu M, Liang H, Xu L. Comparison of CT and MRI in diagnosis of cerebrospinal leak induced by multiple fractures of skull base. Radiol Oncol 2011;45(2):91–96
19 Litschel R, Kühnel TS, Weber R. Frontobasal fractures. Facial Plast Surg 2015;31(4):332–344
20 Zapalac JS, Marple BF, Schwade ND. Skull base cerebrospinal fluid fistulas: a comprehensive diagnostic algorithm. Otolaryngol Head Neck Surg 2002;126(6):669–676
21 Oakley GM, Alt JA, Schlosser RJ, Harvey RJ, Orlandi RR. Diagnosis of cerebrospinal fluid rhinorrhea: an evidence-based review with recommendations. Int Forum Allergy Rhinol 2016;6(1):8–16
22 Cui S, Han D, Zhou B, et al. Endoscopic endonasal surgery for recurrent cerebrospinal fluid rhinorrhea. Acta Otolaryngol 2010; 130(10):1169–1174
23 Tyagi I, Syal R, Goyal A. Cerebrospinal fluid otorhinorrhoea due to inner-ear malformations: clinical presentation and new perspectives in management. J Laryngol Otol 2005;119(9):714–718
24 Chen XB, Liu ZG, Yuan JB, Tian HW. [Application of three-dimensional virtual technology in mandibular defects reconstruction with free fibular flap]. Shanghai Kou Qiang Yi Xue 2015;24(4): 460–464
25 Heckler FR. Discussion of frontal sinus fractures: guidelines to management. Plast Reconstr Surg 1987
26 Rohrich RJ, Hollier LH. Management of frontal sinus fractures. Changing concepts. Clin Plast Surg 1992;19(1):219–232
27 Oakley GM, Orlandi RR, Woodworth BA, Batra PS, Alt JA. Management of cerebrospinal fluid rhinorrhea: an evidence-based review with recommendations. Int Forum Allergy Rhinol 2016;6(1):17–24

28 Senior BA, Jafri K, Benninger M. Safety and efficacy of endoscopic repair of CSF leaks and encephaloceles: a survey of the members of the American Rhinologic Society. Am J Rhinol 2001;15(1):21–25
29 Psaltis AJ, Schlosser RJ, Banks CA, Yawn J, Soler ZM. A systematic review of the endoscopic repair of cerebrospinal fluid leaks. Otolaryngol Head Neck Surg 2012;147(2):196–203
30 Yeo NK, Cho GS, Kim CJ, et al. The effectiveness of lumbar drainage in the conservative and surgical treatment of traumatic cerebrospinal fluid rhinorrhea. Acta Otolaryngol 2013;133(1):82–90
31 White DR, Dubin MG, Senior BA. Endoscopic repair of cerebrospinal fluid leaks after neurosurgical procedures. Am J Otolaryngol 2003;24(4):213–216
32 Ransom ER, Palmer JN, Kennedy DW, Chiu AG. Assessing risk/benefit of lumbar drain use for endoscopic skull-base surgery. Int Forum Allergy Rhinol 2011;1(3):173–177
33 Gücer G, Viernstein L. Long-term intracranial pressure recording in the management of pseudotumor cerebri. J Neurosurg 1978; 49(2):256–263
34 Chaaban MR, Illing E, Riley KO, Woodworth BA. Acetazolamide for high intracranial pressure cerebrospinal fluid leaks. Int Forum Allergy Rhinol 2013;3(9):718–721
35 Choi M, Li Y, Shapiro SA, Havlik RJ, Flores RL. A 10-year review of frontal sinus fractures: clinical outcomes of conservative management of posterior table fractures. Plast Reconstr Surg 2012;130(2): 399–406
36 Appelbaum E. Meningitis following trauma to the head and face. JAMA 1960;173:1818–1822
37 Brodie HA. Prophylactic antibiotics for posttraumatic cerebrospinal fluid fistulae. A meta-analysis. Arch Otolaryngol Head Neck Surg 1997;123(7):749–752
38 Hegazy HM, Carrau RL, Snyderman CH, Kassam A, Zweig J. Transnasal endoscopic repair of cerebrospinal fluid rhinorrhea: a meta-analysis. Laryngoscope 2000;110(7):1166–1172
39 Locatelli D, Rampa F, Acchiardi I, Bignami M, De Bernardi F, Castelnuovo P. Endoscopic endonasal approaches for repair of cerebrospinal fluid leaks: nine-year experience. Neurosurgery 2006;58(4, Suppl 2):ONS-246–ONS-256, ONS-256–ONS-257
40 Bibas AG, Skia B, Hickey SA. Transnasal endoscopic repair of cerebrospinal fluid rhinorrhoea. Br J Neurosurg 2000;14(1):49–52
41 Woodworth BA, Schlosser RJ, Palmer JN. Endoscopic repair of frontal sinus cerebrospinal fluid leaks. J Laryngol Otol 2005; 119(9):709–713
42 Jones V, Virgin F, Riley K, Woodworth BA. Changing paradigms in frontal sinus cerebrospinal fluid leak repair. Int Forum Allergy Rhinol 2012;2(3):227–232
43 Lobo B, Heng A, Barkhoudarian G, Griffiths CF, Kelly DF. The expanding role of the endonasal endoscopic approach in pituitary and skull base surgery: A 2014 perspective. Surg Neurol Int 2015; 6:82
44 Patron V, Roger V, Moreau S, et al. State of the art of endoscopic frontal sinus cerebrospinal fluid leak repair. Eur Ann Otorhinolaryngol Head Neck Dis 2015;132(6):347–352
45 Saafan ME, Albirmawy OA, Tomoum MO. Sandwich grafting technique for endoscopic endonasal repair of cerebrospinal fluid rhinorrhoea. Eur Arch Otorhinolaryngol 2014;271(5):1073–1079
46 Virgin F, Barañano CF, Riley K, Woodworth BA. Frontal sinus skull base defect repair using the pedicled nasoseptal flap. Otolaryngol Head Neck Surg 2011;145(2):338–340
47 Kassam A, Carrau RL, Snyderman CH, Gardner P, Mintz A. Evolution of reconstructive techniques following endoscopic expanded endonasal approaches. Neurosurg Focus 2005;19(1):E8
48 Soudry E, Turner JH, Nayak JV, Hwang PH. Endoscopic reconstruction of surgically created skull base defects: a systematic review. Otolaryngol Head Neck Surg 2014;150(5):730–738
49 Clavenna MJ, Turner JH, Chandra RK. Pedicled flaps in endoscopic skull base reconstruction: review of current techniques. Curr Opin Otolaryngol Head Neck Surg 2015;23(1):71–77
50 Ratilal BO, Costa J, Pappamikail L, Sampaio C. Antibiotic prophylaxis for preventing meningitis in patients with basilar skull fractures. Cochrane Database Syst Rev 2015;4:CD004884
51 Brown SM, Anand VK, Tabaee A, Schwartz TH. Role of perioperative antibiotics in endoscopic skull base surgery. Laryngoscope 2007;117(9):1528–1532
52 Briggs RJ, Wormald PJ. Endoscopic transnasal intradural repair of anterior skull base cerebrospinal fluid fistulae. J Clin Neurosci 2004;11(6):597–599
53 Benzil DL, Robotti E, Dagi TF, Sullivan P, Bevivino JR, Knuckey NW. Early single-stage repair of complex craniofacial trauma. Neurosurgery 1992;30(2):166–171, discussion 171–172
54 Friedman JA, Ebersold MJ, Quast LM. Post-traumatic cerebrospinal fluid leakage. World J Surg 2001;25(8):1062–1066
55 Neligan PC, Mulholland S, Irish J, et al. Flap selection in cranial base reconstruction. Plast Reconstr Surg 1996;98(7):1159–1166, discussion 1167–1168
56 Califano J, Cordeiro PG, Disa JJ, et al. Anterior cranial base reconstruction using free tissue transfer: changing trends. Head Neck 2003;25(2):89–96
57 Costa H, Cerejo A, Baptista A, et al. The galea frontalis myofascial flap in anterior fossa CSF leaks. Br J Plast Surg 1993;46(6):503–507
58 Rocchi G, Caroli E, Belli E, Salvati M, Cimatti M, Delfini R. Severe craniofacial fractures with frontobasal involvement and cerebrospinal fluid fistula: indications for surgical repair. Surg Neurol 2005;63(6):559–563, discussion 563–564
59 Guy WM, Brissett AE. Contemporary management of traumatic fractures of the frontal sinus. Otolaryngol Clin North Am 2013; 46(5):733–748
60 Kral T, Zentner J, Vieweg U, Solymosi L, Schramm J. Diagnosis and treatment of frontobasal skull fractures. Neurosurg Rev 1997; 20(1):19–23
61 Klastersky J, Sadeghi M, Brihaye J. Antimicrobial prophylaxis in patients with rhinorrhea or otorrhea: a double-blind study. Surg Neurol 1976;6(2):111–114
62 Dahiya R, Keller JD, Litofsky NS, Bankey PE, Bonassar LJ, Megerian CA. Temporal bone fractures: otic capsule sparing versus otic capsule violating clinical and radiographic considerations. J Trauma 1999;47(6):1079–1083
63 Nishiike S, Miyao Y, Gouda S, et al. Brain herniation into the middle ear following temporal bone fracture. Acta Otolaryngol 2005; 125(8):902–905
64 Lin DT, Lin AC. Surgical treatment of traumatic injuries of the cranial base. Otolaryngol Clin North Am 2013;46(5):749–757
65 Leech PJ, Paterson A. Conservative and operative management for cerebrospinal-fluid leakage after closed head injury. Lancet 1973; 1(7811):1013–1016
66 Nosan DK, Benecke JE Jr, Murr AH. Current perspective on temporal bone trauma. Otolaryngol Head Neck Surg 1997;117(1):67–71
67 MacGee EE, Cauthen JC, Brackett CE. Meningitis following acute traumatic cerebrospinal fluid fistula. J Neurosurg 1970;33(3): 312–316
68 Coker NJ, Jenkins HA, Fisch U. Obliteration of the middle ear and mastoid cleft in subtotal petrosectomy: indications, technique, and results. Ann Otol Rhinol Laryngol 1986;95(1, Pt 1):5–11
69 Kveton JF. Obliteration of mastoid and middle ear for severe trauma to the temporal bone. Laryngoscope 1987;97(12): 1385–1387
70 Adkins WY, Osguthorpe JD. Mini-craniotomy for management of CSF otorrhea from tegmen defects. Laryngoscope 1983;93(8): 1038–1040